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SCIENTIFIC THEORETICAL PROBLEMS OF VALIDATING THE SYSTEM FOR SOCIOPSYCHOLOGICAL SCREENING OF FLIGHT PERSONNEL

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 10 Jul 86) pp 4-7

[Article by V. L. Marishchuk and V. I. Yevdokimov]

[English abstract from source] A large number of flight accidents and catastrophes associated with the human factor, high nervous and psychic tension when being on duty, increasing trend towards a greater incidence of psychogenic diseases responsible for pilots to be grounded make it necessary to develop a system of primary psychoprophylaxis of the flying personnel and to help them with various social, psychohygienic and psychoprophylactic measures. This paper presents basic psychoprophylactic measures of medical expertise, professional training and psychological selection. Proper development of these measures will contribute to flight safety and pilot longevity.

[Text] In the age of the scientific and technological revolution, problems of safeguarding and strengthening health, preventing neuropsychiatric diseases acquire relevance to the national economy. This is particularly important in aviation work, which proceeds under extreme conditions, sometimes at the limit of man's psychological and psychophysiological capacities.

The many (up to 70-80%) aircraft accidents and catastrophes related to the human factor [1, 16-18], high degree of nervous and mental stress observed during flight work [1, 9, 16, 17], the progressive tendency toward increased incidence of psychogenically determined diseases (neurotic states and psychosomatic disorders) in the structure of morbidity and grounding of flight personnel [4, 26] make it imperative to search for new forms, means and methods of extensive social, psychohygienic and psychoprophylactic measures, as well as validation of a system of primary psychoprophylaxis.

Commanders, political workers, physicians, aviation psychologists and pedagogues are involved in solving problems of psychopropnylaxis to safeguard and strengthen mental health of flight personnel. Foreign researchers [23, 25] have also indicated the need for a joint effort to prevent stress situations in the work of flight personnel.

Expert medical certifi ation of flight personnel presently provides a prognosis for the so-called "static" health status. The methods and procedures of expert medical cerficiation do not permit sufficient consideration of the functional capacities of the body, its psychophysiological reserves, and they do not always prognosticate a weak point in the body, the "specificity factor," the possibility of onset (and consequently of specific prevention) of some psychosomatic disorders or other, which play the leading role among causes of disqualifying flight personnel for health reasons. For example, the hemodynamic variant of regulation of circulation is not always evaluated well enough, yet it is expressly on its basis that one can predict rather reliably the degree of adaptation of the circulatory system to extreme environmental factors [7].

As before, there is still the acute question of "adverse" personality traits of flight personnel, with regard to possible inadequate means of mental adaptation of the personality to extreme activities and complicated conditions of social function, since the guidelines and methods of psychological expertise have not yet been definitively developed (including the question of including a psychiatrists in the commission for expert medical certification of flight personnel), but some positive results have already been obtained in this direction [11, 19, 24, 26].

An increase in number of physicians per se could hardly enhance appreciably the psychopropnylactic direction of aviation medicine [21]. A different approach is needed to the system of expert medical certification of flight personnel, pilot personaltiy and his professional performance. In this regard, some foreign aviation physicians deem it mandatory for medical experts in different specialties to devote most of the time spent on examining a pilot on elicitng the psychogenic factors of personal and professional life [22, 23, 25].

Commanders and political workers do not make a full enough study of the needs and requirements of their subordinates, of their personality traits. Many superiors, who allow flight personnel to perform a flight assignment do not consider the psychological readiness of individuals, the nature of their domestic relations, behavior at home, although it has been proven convincingly [8, 13, 14, 15, 22] and we have often observed in practice that expressly these factors often lead, in the presence of extreme situations, to deadaptation, psychogenic diseases and aviation accidents.

No clearcut parameters of mental readiness for a flight have yet been elaborated, although motivational and psychophysiological parameters are used as its criteria, as well as the results of special professional talks, observation of behavioral reactions, manifestations of emotions and conversations of flight personnel [5, 13, 16].

It is only by including, in conversations with pilots, questions concerning changes in sleep, mealtime, personal habit, etc. stereotypes that one can detect with a high degree of probability pilots with a tendency toward flight incidents and psychogenic diseases [16, 25]. For this reason, it is not by chance that the opinion is held that evaluation of psychological readiness for a flight must be included in preflight professional and medical checkups [5].

Viewing vocational training as one of the complex and intense factors in human endeavor, R. N. Makarov [12] validated a system of professional training of flight personnel, in which a large place is devoted to psychophysiological trianing.

It should be noted that little use is still being made of the corrective influence of ground instructors on formation of the required professional qualities in student pilots, in particular, due to the virtually total lack of interaction between the pedagogic personnel and professional screening specialists.

Extended screening is not being adopted adequately in the pedagogic process, although one could obtain early information about many personality traits of cadets and, on its basis, implement the necessary measures even prior to flight training, in the period of theoretical instruction and simulator training [13].

As yet, instruction using psychoregulation methods has not been included in the program of psychophysiological training of flight personnel, since the method of psychoregulation training is a means of individual correction of tbe psychophysiological state. Various forms of sociopsychological training can be considered more promising for the purpose of psychoprophylaxis and greater safety of flights.

Specialists in social and medical psychology have demonstrated the effect of interpersonal relations factors on the health status of members of a group. Reliability of performance of a flight assignment depends largely on smooth actions by the flight crew, flight control groups and their back-up. This is why the opinion has been voiced that there must be deeper investigation of the sociopsychological distinctions of flight school cadets [3, 11, 13, 18].

Pedagogic observations of flying school cadets have shown that a number of social personality traits of professional importance were usually stable throughout the instruction period and were less subject to correction than psychophysiological and physical properties [13]. However, expressly these traits (honesty, discipline, industriousness, esprit de corps, etc.) determined not only the capacity for training, but the nature of subsequent professional performance [13].

Experience in work at flying schools shows that cadets with overtly adverse sociopsychological circumstances in personality formation (there are usually up to 15-20% such cadets) present serious problems in subsequent flight training. A study of a sample of about 200 people using personality tests and methods of statistical analysis[1] established the cause of this phenomenon. The subjects revealed early personality changes which were manifested in the form of accentuations, circumscribed neurotic states. In everyday life, they did not have a noticeable effect on behavioral reactions, but under difficult and extreme conditions these changes caused onset of psychological deadaptation in such cadets. They constituted a risk group with respect to onset of psychogehic diseases and professional inappropriateness. Special mention should be made of the fact that the structure-forming factor of sociopsychological screening--the sociopsychological profile--is the basic factor that links screening with the system of primary psychoprophylaxis.

The following system of sociopsychological screening is offered on the basis of the foregoing, as applied to periods of professional instruction and professional work.

I. Period of Immediate Screening (Vocational Guidance)

1. Comprehensive investigation of cadets' personal affairs, educational, former job and Komsomol references. A form of work such as correspondence with an enterprise or school to learn all about some of the circumstances mentioned in the references is also not ruled out.

2. Examination with use of medical psychological tests (personality, sociometric and projective methods). At the present time, the question of using personality tests is still debatable. Of course, one could hardly expect that some personality test scales have a direct bearing on success of flight training. However, use of these tests yields valuable information about the methods of psychological adaptation of the individual, his main individual psychological distinctions, metntal state and other information that would be impossible to obtain in such a short time [11, 18, 19]. Of course, the information extracted by means of personality tests is not always sufficient, and the processes of interpreting test data are time consuming. Adoption of automated procedures for primary interpretation of test data makes it possible to organize screening of large groups within a relatively short time.

3. Conversation of psychologist (or experienced specialist in the sector) with the cadet in order to define the motivational aspects of the personality and results of experimental psychological tests. This talk must touch upon early periods in the cadet's life, since it is expressly at these times that the most significant social relations are established.

4. Sociopedagogic observation by subunit [podrazdeleniye] commanders during assemblies. For example, the commanders enter daily in the subunit rosters the most important featues of cadets or give them marks for discipline, industriousness, social activity, communication and leadership qualities, etc.

5. Integrative evaluation of sociopsychological screening, in which the results of experimental spychological testing, talk and observations are taken into consideration.

II. Period of Extended Screening (Professional Work)

1. Flight groups are manned with consideration of the principle of psychological compatibility. The results of a sociometric interrogation, which are checked against information about cadets referred from subunits, education department, medical service, results of professional-pedagogic observation and experimental psychological examination are used as the basis for forming groups.

2. Formation of flight crews (flight group--pilot--instructor system). The recommendations of commanders, tenure and experience, results of examinations using personality tests are considered when manning flight crews.

Analysis of efficacy of even a few aspects of introduction of sociopsychological screening revealed that it was very important. There was a decrease in total number of grounded cadets ($p<0.01$), including those grounded for health reasons ($p<0.05$). A comparison of cadets grounded for health reasons who were not subject to sociopsychological screening revealed that there was an appreciable decrease in number of psychogenic diseases, from 62 to 41% ($p<0.05$) in the structure of morbidity that became the cause of grounding.

Integrated solution of problems touched upon here will aid in longevity of flight personnel and flight safety.

FOOTNOTES

1. The authors wish to express their profound gratitude to L. P. Petrenyuk and V. N. Lysenko for performing correlation and factor analysis of the test results.

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FORMATION OF SPATIAL POSITION IMAGE WITH ONSET OF ILLUSIONS OF VESTIBULAR ORIGIN

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 6 Mar 86) pp 7-12

[Article by O. A. Vorobyev and V. V. Ivanov]

[English abstract from source] This paper discusses specific features of pilot's spatial orientation in response to spatial illusions of vestibular origin associated with their recognition and management. Analysis of data in the literature and observations by the present authors allow the conclusion that pilot's spatial orientation, once spatial illusions have emerged, makes him assess not only the instrumental information but also the pattern of his own controlling movements. As a consequence, it is suggested that in relation to the formation of a correct image of spatial position (particularly in the case of spatial illusions) pilot's controlling movements act as part of instrumental information concerning the spatial position of the flying vehicle.

[Text] It is known that illusions of spatial position (ISP) that occur during flight make it difficult, in a number of instances, for the pilot to be oriented in space, complicate his professional work and could serve as the cause of conditions leading to accidents [18]. As aviation develops, the number of flight accidents related to impaired spatial orientation is increasing [19, 21]. This is indicative of the importance of proper understanding of the essence (mechanisms) of the process of spatial orientation of pilots with onset of illusions for the purpose of refining the system of preventive measures.

V. A. Ponomarenko et al. [14] proposed an original conception for control of illusions, which consists of voluntary control of one's sensations on the basis of distinct awareness of the latter. However, there has not been any discussion in the literature of the question of how to become aware of illusions. Yet this is rather important, since in the presence of a persistent illusion efforts to convince oneself that "the truth lies in the instruments" often fail to be helpful [7]. In the opinion of flight personnel [9], ISP have an adverse effect also on performance of the flight assignment as a whole in 3.6% of the cases. For this reason, on the basis of the foregoing, our objective here was to analyze the distinctions of pilot spatial orientation with onset of ISP of vestibular genesis, related to awareness and overcoming the latter, on the basis of results of our own studies and data in the literature.

With onset of ISP, the objective position of a flight vehicle in space, as determined on the basis of instrument information, does not conform to the subjective sensations of position, and under such conditions the pilot exerts considerable volitional efforts to make sure that the instruments are not malfunctioning, to overcome the involuntary desire to fly the aircraft according to his immediate perception, to overcome the "false" graphic displays showing the position of the aircraft [2, 5]. The difficulty and, in a number of instances, failure of this struggle consist of the fact that the sensory cues with ISP are not unusual to the pilot, from the standpoint of their psychophysiological meaning, since they are adequate and natural reactions of sensory systems to the effects of dynamic flight factors. Illusory sensations are "false" only in the sense that the image of spatial position formed on their basis does not correspond to the aircraft's (and actually the pilot's) true spatial position, since they arise in most cases[1] in response to the effect of unusual combinations of sense organ stimuli that are not encountered in man's everyday life [9]. As to illusions of sense organs that arise under the effect of unusual stimulation, even Helmholtz stressed the fact that, in such cases it is obvious that there is nothing wrong in the function of sense organs and corresponding neural mechanisms; both are governed by laws that are constantly in effect, while illusions are the result of interpreation of sensory perceptions [5]. It is expressly the "naturalness" (reality) of subjective coloration of illusory sensations that causes the difficulties experienced by the pilot when he tries to fly only by instruments. This situation is also complicated by the fact that pilots usually fly using noninstrument information in addition to instruments [2, 15]. For this reason, intellectual efforts alone very rarely enable subjects to overcome experimentally induced illusions [8].

In recent years, the opinion has been expounded that a pilot must purposefully select information and deliberately form an image of spatial position for successful spatial orientation under difficult flying conditions [2]. However, in this respect, researchers concentrate mainly on visual information and considerably less attention is given to the sensorimotor component of inflight spatial orientation.

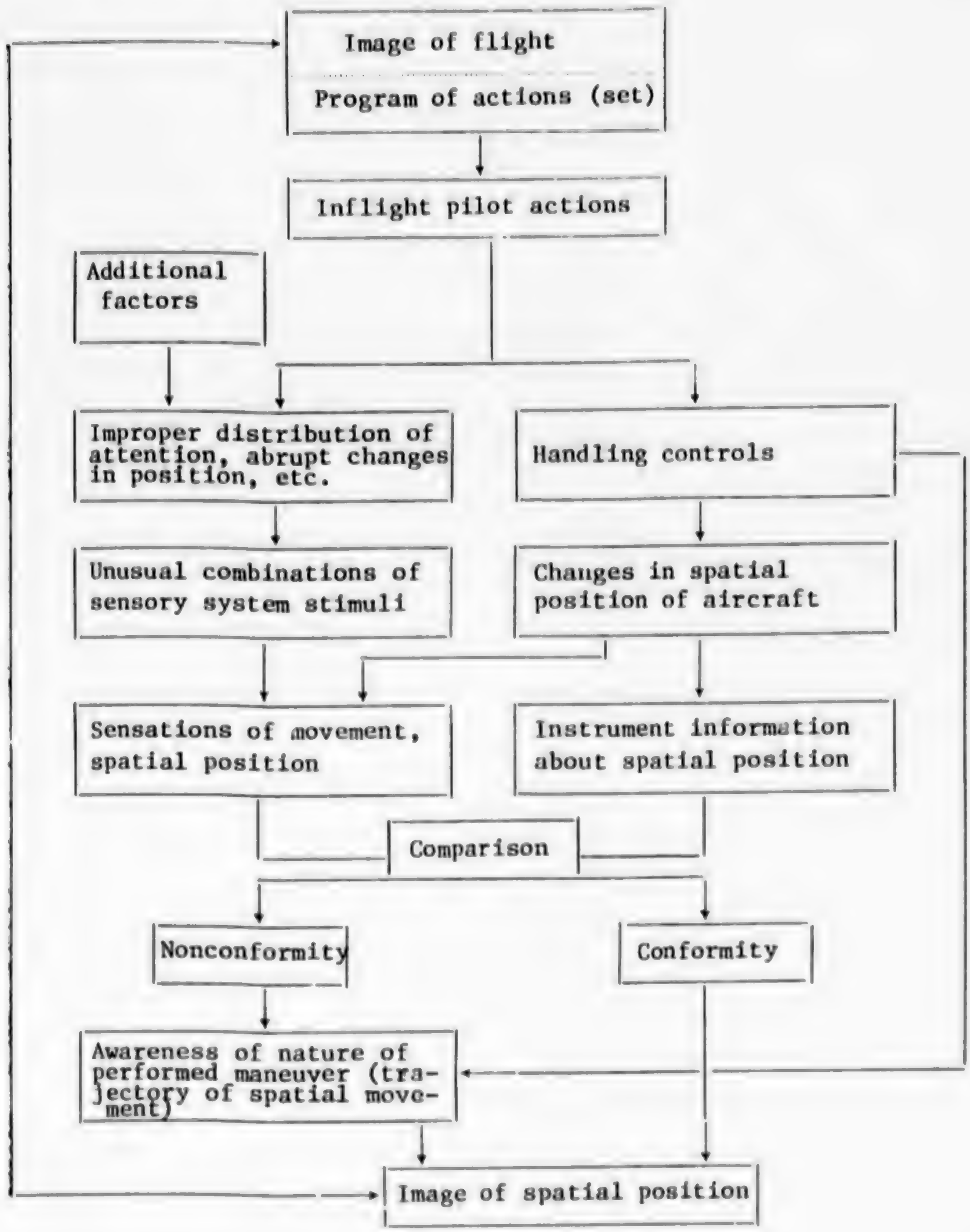
It has been established to date that perception (including spatial perception) is not a passive process on the part of the subject, due only to the effect of some stimuli on receptors. It has been proven that active movements are of deciding importance in formation of visual and other images [10, 11]. The multifunctional role of the muscular analyzer is stressed, as a mandatory component of interanalyzer integration and constant afferent system in implementation of spatial analysis [1].

From the standpoing of modern "physiology of activity" (developed by N. A. Bernshteyn, P. K. Anokhin and their proponents), all physiological functions, ranging from elementary to the most complex, are viewed as hierarchically organized systems that are formed in a closed circle and cobtain a special apparatus (referred to as "motor task," "acceptor of action," etc.) that predetermines all functions [17]. This can apply in full to spatial analysis, since it is noted in the work of V. A. Ponomarenko et al. [14] that formation of an acceptor of action result, which determines the direction of integration of afferent stimuli, is apparently the neurophysiological basis of a subject's set in the course of formation of an image of spatial position.

The distinctions of a pilot's spatial orientation in flight are attributable primarily to replacement of the system of coordinates (for the basis of which the gravity-inertial resultant is taken, rather than the vector of earth's gravity). In addition, unlike conditions on the ground, an inflight change in spatial position does not occur because of active body movements, but as a result of manipulation of aircraft controls. For this reason, there is considerably reduction in range of active movements made by man that enable him to "palpate" space with his analyzers and, consequently, actively perceive space under complicated dynamic conditions. In this regard, it can be considered that pilot actions pertaining to control of the aircraft are the main source of sensorimotor cues about inflight spatial position. Indeed, when pilots with experience in flying under difficult meteorological conditions were given the task of defining spatial evolution of the aircraft on the basis of instruments alone, without controlling the aircraft, they often made mistakes in determining its spatial position [13]. Previous studies [3] also showed that, during rotation on a small centrifuge (with simulation of illusion of banking), adequate perception of spatial coordinates in determining the position of the body in relation to the direction of the resultant of gravity-inertial force is achieved by manipulating a special lever, analogous in principle to the operation of the aircraft's control, whereas the sensation of "banking" diminishes with increase in rotation time. Thus, as shown by the above facts, with regard to spatial perception too, one should proceed from the thesis convincingly validated by Soviet scientists that it is expressly during activity that there is formation of a subjective sensory image, and for this reason, in order to comprehend the distinctions of its formation it is necessary to investigate (in addition to lay-out and function of sense organs and physical characteristics of stimuli) the activity of the subject who effects its link with the substantive world in a concrete situation [11, 12].

The above considerations warrant the belief that pilot spatial orientation with onset of ISP requires active direction of awareness to assess not only the received flow of instrument information, but controlling actions. Consequently, it can be considered that perception of spatial position must be included in the actions to control the aircraft and only then will there be active perception of space [4, 16]. In other words, the process of formation of an image of spatial position with onset of ISP must include analysis of all elements of the functional system of spatial orientation, including its sensorimotor component. Indeed, as shown previously [14], more extensive mental actions to operate with spatial conceptions are related to more marked motor activity in flight (performance of gnostic movements of aircraft controls when coming out of a difficult position). The accuracy or fallaciousness of pilot perception of his spatial position under difficult flying conditions is established on the basis of conformity of control movements to current or preceding actions. In other words, the controlling actions of the pilot can be viewed as the "reference points" for separating illusory and real sensations of spatial position in a situation where instrument information does not conform to the pilot's sensations and he wonders, "What should I trust?" As a result, the assumption might be voiced that the pilot's controlling actions pertaining to formation of the proper image of spatial position (particularly in the presence of ISP) emerge as instrument information about the spatial position of the aircraft.

Hypothetical chart of formation of image of spatial position under unique flying conditions in the absence and presence of illusions of vestibular genesis



*Additional factors include interruptions in flying work, disruption of work and rest schedule, illnesses [9].

On the basis of analysis, a system was elaborated for formation of image of spatial position under difficult flying conditions in the absence and with onset of ISP. This chart, which takes into consideration the previously proposed approach with regard to illusions of diverse origin and genuine acceleration perceptions in flight [9], reflects the need, which has been validated here, for different routes of formation of spatial position image when instrument information is consistent and inconsistent with the pilot's perception of spatial position. Construction and maintenance of the correct image of spatial position in the absence of ISP are assumed to be governed by previously described mechanisms [14], whereas with onset of ISP they occur on the basis of analysis of conformity of instrument information received, noninstrument cues about spatial position and nature of actions in using controls.

It is also necessary to take into consideration the fact that during instrument flights there is mental visualization of the spatial situation [6]. But, in the presence of ISP, such visualization is difficult due to presence of a visual component in the illusional sensations, since the pilot sees an "inclination" of aircraft cockpit canopy casements, as shown by the answers to a questionnaire filled out by flight personnel. The difficulty in suppressing the visual component of an illusion by perceiving instrument information consists of the fact that the visual component of ISP is realized primarily by the peripheral fields of vision, which play the leading role in perception of motion [20]. Moreover, in many cases ISP occurs expressly due to presence of stimulation of peripheral fields of vision (edge of cloud formation, one-sided illumination of cockpit by the sun, etc.) in the absence of visibility of the real horizon [9].

For this reason, to construct a correct image of spatial position in the presence of illusions of vestibular genesis (according to the submitted chart), the pilot must analyze, on the basis of instrument readings and controlling actions, the nature of the maneuver he is performing (i.e., trajectory of movement in space) and mentally conceive of the dynamics of the visual situation outside the cockpit, which could have been present during visual flight with performance of the same aircraft maneuver. Such imagination by the pilot of "movement" of the horizon, ground-based reference points (rather than their stationary spatial position, which is of basic importance) would enable him to make maximum use of physiological mechanisms for spatial orientation and thereby help overcome illusions and build the correct image of the spatial position as the basis of inflight spatial orientation of the pilot.

The views expressed here on the genesis and means of overcoming inflight ISP definitely require further experimental work and theoretical development.

FOOTNOTES

1. We shall not deal here with any possible conditioned reflex and other mechanisms of onset of ISP.

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ALCOHOL, EMOTIONS, STRESS AND PERFORMANCE

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[English abstract from source] The uncompromising struggle against drunkenness and alcoholism can be successful provided that not only social but also biomedical nature of the phenomenon is adequately understood. It is important to note that alcoholism is the most widespread type of drug addiction which results in the mental dependence on the induced euphoria state and deceptive antistressor effect. In fact, alcohol, even in low doses, causes erroneous assessment of current events, impairment of the performance level and degradation of normal relationships with other people. Euphoria which is subjectively perceived as a happy sensation develops as a result of the narcotic effect of alcohol on the central nervous system, atrophic degeneration of neurons in the dorso-lateral part of the frontal compartment and subsequent development of destructive processes in other brain compartments. The development of the domineering pathological need for alcohol invariably leads to changes in the scope and pattern of normal activities. It is however obvious that man's activities the purpose of which is to satisfy material and intellectual requirements act as a source of strong and natural emotions. As follows from the experience accumulated by American and Canadian airlines, prevention, treatment and rehabilitation of alcoholic pilots should be based on modern concepts about the mechanisms underlying the development of stable pathological systems and their elimination by producing stable functional-antagonistic antisystems.

[Text] The drinking and alcoholism probem requires the closest attention of physicians and biologists. To wage an uncompromising war against drunkenness as a socially intolerable phenomenon, it is necessary to change the attitude toward traditions that were formed and implanted for centuries. But in order to do this, it is important to understand not only the social, but biological nature of this phenomenon. We must have the opportunity to gain fuller knowledge about the basic properties of alcohol and mechanisms of development of a pathological addiction to it.

The social hazard of distribution and consumption of alcoholic beverages was realized long ago, as indicated by legislative measures instituted to control excessive drinking. In China, for example, consumption of wine was totally banned in 1120 BC, and vineyards were eradicated. Later on, in accordance with the ethical conceptions of the ancient Chinese philosopher, Confucius (551-478 BC), heavy drinking was forbidden by imperial decree under penalty of death. In Greece, in the times of the Athenian lawgiver, Draco, in the 7th century BC, the death penalty was also imposed for repeated heavy drinking.

In the absence of social and religious bans, drinking occurred at times on a mass scale. In Ancient Rome, the cult of Bacchus, the god of wine and merriment was popular. In 496 BC, a temple was erected in honor of Bacchus, and mass scale celebrations were organized in his honor--orgies. The harm of these orgies was so obvious that they were banned by the Roman senate in 186 BC, and later on, the Roman emperor Domitian (61-91 AD) ordered eradication of half the vineyards and forbade subsequent planting of grapevines in order to reduce wine production [48, 49].

The danger of wine abuse was mentioned as far back as 1500 BC in a treatise on rules of behavior in Ancient Egypt. The outstanding physicians of ancient Medicine, Hippocrates (ca 460-377 BC) and Galen (ca 130-200 AD) wrote about the harm of excessive drinking. The French philosopher of the Renaissance, M. Montaigne, wrote in his work, "Experiments," in the chapter entitled "On Excessive Drinking": "Among other sins, excessive drinking is a particularly gross and lowly fault" (quoted from I. A. Sytinskiy, 1979). In the early 19th century (1817-1819), the Moscow physicians Salvatori and Bril-Kramer described the clinical signs of alcoholism, and in 1849 Magnus Guss proposed that this disease be called chronic alcoholism. The term, alcoholism, was first introduced in the Russian dictionary of Ya. K. Grot in 1891.

Thus, people realized long ago the devastatic consequences of alcohol consumption. What then is the reason for the persistence and widespread nature of this dangerous social phenomenon?

E. Steglin [44], in an explanation of the causes prompting people to resort to addictive toxic agents and, first of all, to alcohol, states that there are times in the life of everyone when one wants to eliminate dysphoric moods, restore impaired spiritual equilibrium, attenuate the acuity of conflicts or forget about them, shed the burden of tormenting anxiety or guilt feelings. However, it is very often impossible to alter one's environment, and it is also far from always possible to eliminate one's difficult experiences through an effort of will, and thus the temptation to achieve this goal rapidly and easily by intake of a substance that gives pleasure if only because it attenuates or suppresses the feeling of dissatisfaction is understandable.

With a mild degree of inebriation (about 100 mℓ 40° vodka) the affect is improved, and this is associated with the sensation of increased energy, verbal and psychomotor disinhibition, faster flow of thoughts. A tendency toward corase humor and primitive jokes appears, there is less self-control, as well as a less critical attitude toward oneself and one's capabilities. The sensation of internal physical and mental comfort appears.

With moderate intoxication (about 200 mℓ 40° vodka), there is impairment of attention, appearance of distraction and disorganized thinking, groundless merriment and foolishness or, on the contrary, restlessness, touchiness and tearfulness. Sometimes, people become suspicious, angry and aggressive. Their speech becomes dysarthric and their gait is unstable.

With severe intoxi ion (about 400 mℓ 40° vodka), one observes disorientation as to time and space, slurred speech, uncoordinated movements and loss of consciousness. Analgesia and anesthesia develop. Acute alcohol intoxication (over 800 mℓ 40° vodka) is characterized by profound dazed state changing to coma. Death occurs as a result of paralysis of the respiratory center.

Frequent intake of alcohol alters the nature and severity of its effects; to obtain the inebriating effect one has to increase the dosage of alcohol 2-fold or more. The dosage is 3-4 times increased for alcoholics. Regular intake of alcohol in large doses leads to alcoholism and, once it has developed, alcoholism often persists as a disease for a lifetime [3, 23, 32, 35, 45-47, 51-52].

Alcoholism is a disease with progressive course, which is characterized by the syndrome of addiction and specific somatic and neuropsychological disorders. The following are considered the chief signs of alcoholism by addiction specialists: tolerance with loss of protective vomiting reflex, psychological dependence--unsurmountable addiction to alcohol because of its euphoric effect, physical addiction -need for regular intake of alcohol to prevent and curb the withdrawal syndrome [19, 36, 59].

With a maximum tolerance level, the dosage of alcohol required to induce intoxication must be increased by many times (sometimes up to 8-12 times); however, in advanced cases of alcoholism, there is dramatic decrease in tolerance to alcohol, which is indicative of depletion of compensatory and adaptive mechanisms.

Psychological dependence is the result of appearance in the brain of a persistent alcohol dominant, which maintains pathological addiction to the emotional state--euphoria--artificially induced by alcohol. Appearance of a positively colored alcoholic dominant distorts thinking and emotional perception of reality, lowers the subjective relevance of material and spiritual values and alters social orientation of the personality.

Physical dependence is the result of a qualitative change in functional state of the body with persistent metabolic changes that fix on a pathological level of vital functions. In order to function on this level, the body requires constant intake of alcohol.

We know of a conception, according to which all of the observed effects of alcohol are primarily attributable to its interaction with various cellular and subcellular membranes [56]. On this basis, the membrane-damaging effect of ethyl alcohol as a concrete manifestation of its toxic effect on the body is the primary cause of the pathology that it elicits. The severity of the latter depends not only on the dosage of alcohol, but initial structural and functional state of membranes, which is probably what determines, in the

broadest sense, nonspecific resistance to diverse physicochemical stress factors that elicit the systemic adaptive reaction referred to by H. Selye as the "general adaptation syndrome" [40]. From this vantage point, ethyl alcohol, like substances that are similar to it in structure and action, for example, ethyl ether, which is used extensively in anesthesiological practice, should be viewed as a stressor agent [40], while ethanol abuse should be viewed as a form of self-aggressive behavior due to the pathological need for alcohol [20].

Alcohol has a dual effect on brain functions: by altering biochemical and electrophysiological processes in neurons under the effect of the ethanol molecule itself, and as a result of formation in the course of its metabolism of neuroactive and neurotoxic compounds which, in turn, elicit diverse neuropharmacological effects [7, 27, 28, 48, 49]. In particular, a substance has been isolated from the urine of alcoholics, which revealed morphine-like action, and it was formed in the body as a result of interaction between alcohol metabolites and catecholamines [53], while experiments on animals have confirmed the possibility of involvement of opiate structures of the brain in the process of formation of a drug addiction [31].

The brain is the most sensitive to alcohol intoxication. As shown by animal experiments, the first morphofunctional changes are demonstrable in it as early as 10 days after the start of alcohol intake, and thereafter alcohol damage to the brain progresses, causing mass-scale destruction of neurons [7, 8]. These data are consistent with clinical observations, which have confirmed the progressive nature of degenerative changes associated with alcohol intake, which lead to atrophy of the brain. Alcoholism is the most frequent cause of atrophy of the brain in people 40-60 years of age. The most severe lesions are observed in the dorsolateral frontal region, from which the destructive process spreads to other frontal gyri and then to the superior parts of the temperal lobe [55].

The first link in the chain of events that lead to such disastrous consequences is euphoria. Euphoria, which is subjectively perceived as a sense of satisfaction related to experiencing a changing mental and physical state under the influence of alcohol, is considered the prime etiological factor of alcoholism [37, 39]. In the apt expression of I. N. Pyatnitskaya [37] in this regard, "if alcohol would act in the opposite order of its actual effect, not from mental relaxation to paralysis of centers of the medulla oblongata, but the reverse, i.e., if the action of alcohol would start with paralysis of the medulla the problem of excessive drinking would not exist." Indeed, no pathological addiction to toxic agents that do not induce euphoria ever occurs. It is expressly the euphoric effect that is the cause of onset and continuation of alcohol intake, while the psychological dependence that also develops is attributable to the satisfaction factor [37].

The widespread conviction that alcohol can curb manifestations of emotional stress is another equally powerful reason for using alcohol [21, 62]. However, the antistress effect of alcohol is attributable to a significant extent to its euphoric action. It must be noted that a negative emotional background with elements of frustration and desire to alter a difficult situation by means of a euphoric effect is an important factor in the development of alcoholism [67]. This negative background, even if it is not present at the start, develops subseqnetly as the "price" for euphoria. As the disease

progresses, the emotional status gradually worsens with a shift of the balance in the direction of negative emotions, to the extent of appearance of negative experiences with suicidal tendencies.

In order to comprehend the mechanism of development of alcoholic pathology, it is important to distinguish between the specific narcogenic and nonspecific stressogenic effects of alcohol. In presenting his conception of the "general adaptation syndrome," H. Selye stressed that "all of pharmacology must be revised in order to differentiate between changes due to stress and those caused by the specific action of drugs" [40]. The nonspecific stressogenic action of alcohol is based on its deleterious membranotropic properties, while the chief element in the specific narcogenic effect is euphoria. What then is the mechanism of its onset?

From the standpooint of P. K. Anokhin's biological theory of emotions [1], "a positive emotional state on the order of satisfaction of some need arises only if feedback from the results of an action reflects with extreme accuracy all elements of expressly the positive results of this function and for this reason coincide exactly with the parameters of the acceptor of action." Here, acceptor of action refers to a special nervous system with which a model is formed of the anticipated result of action on the basis of dominant motivation and the function of anticipation and comparison is implemented. If the results of an act do not coincide with the parameters of the action acceptor, it immediately leads to a negatibe emotion [1].

"The "expected result" of alcohol intake is appearance of pleasant or disappearance of unpleasant experiences. Since alcohol is a stressor, the emotional system should detect the deleteriousness of its effects. An adequate emotional reaction to the stressor should be manifested by onset of a negative emotion. Moreover, as a result of the mismatch between the "expected result" in the form of pleasant sensations and the state of tension within the limits of the general adaptation syndrome, the negative coloration of the arising emotion must be even more enhanced. But this does not happen in reality. For some reason, the body does "not notice" that it is in a state of stress. Various explanations could be found for this. However, in our opinion, the simplest and most logical is that alcohol *disrupts the physiological function of the emotional system.* The entire chain of events, some of which are dramatic, indicates this, from the first drink to the last.

Thus, euphoria in the presence of alcohol-induced physiological stress occurs as a result of impaired function of the emotional system, and it is a distorted evaluation of the body's internal state, which is inconsistent with the actual nature of the effect. It is only at the elimination stage, when euphoria disappears, that the evaluating function of the emotional system is restored, reacting with dysphoria to the stressful nature of alcoholic intoxication [18, 30]. But, the memory of the emotional experiences in a state of alcoholic euphoria is so strong that individuals subject to pathological addicition again try to reproduce this state, even against their own better judgment [16]. According to the conceptions of N. P. Bekhtereva concerning the mechanisms of formation of stable pathological states [6], a positive emotional state becomes the cause of appearance of a psychological alcohol dominant and related stable state of psychological dependence. The speed of onset and stability of the alcoholic dominant are attributable to the fact that addiction to positive emotions emerges as independent biological motivation [13].

Euphoria and dysphoria are opposite states. In the definition of P. V. Simonov [41, 42], a positive emotion is a state that a living being strives to enhance, extend and, if possible, evoke again, whereas a negative emotion is a state that a living system strives to attenuate, interrupt or prevent. In the race for the former and escape from the latter, the dosage of alcohol must be gradually increased, thereby also increasing its deleterious stressor effect. As a result, the individual becomes a hostage of two polar emotional states--euphoria and dysphoria--and, though it appears apardoxical at first glance, he becomes the victim of the mechanism of biological protection--tolerance.

The perfection of adaptive activity of a highly organized living system is achieved by combining two fundamental needs--self-preservation and self-expression. Actualization of each of these polar needs transforms them into the appropriate motivation for action with adequate emotional accompaniment. Motivation due to the need for self-preservation is associated with negative emotions, whereas motivation due to the need for self-expression is associated with positive emotions. Each type of emotion has its own neurofunctional mechanism, which has been confirmed by the discovery of Olds, who found anatomically circumscribed zones of "encouragement" and "punishment" in the basal regions of the brain [63, 64], and reciprocal relations betwen them [29]. Observations of the effects of stimulation of deep structures of the brain, which was performed on people for therapeutic purposes, also confirm this conception [5, 43, 58, 61, 66]. Still, as noted by A. V. Valdman [49], "emotion as a form of mental activity cannot be related to any isolated structure or level of the brain," "it is formed as a result of combination of many afferentations differing in quality, of both a sensory and motivational nature." Apparently, the euphoric effect of alcohol cannot be related to its influence on any specific brain structure.

As we know, euphoria is a vague phenomenon. It has numerous shadings and arises under the influence of the most diverse factors leading to impairment of brain functions. For this reason, it can be assumed that impairment of excitatory and inhibitory processes is the most probable and general cause of its onset. Inhibitory factors, which repress mechanisms of control and which are affected with any form of pathology since they are the most vulnerable, are constant regulatory factors in all functional systems. They cause disinhibition of activity of structures and repressed processes, and this is what elicits disintegration of a biological system [24]. For this reason, the most logical explanation for the euphoric effect of alcohol is the long- and well-known phenomenon of disinhibition, which is inherent not only in alcohol, but the entire group of narcotic agents [26, 27]. Several authors who have described alcoholic euphoria view it expressly as the result of disinhibition [2, 11, 33].

With disinhibiton, there is release of subcortical emotiogenic structures from the controlling and regulating influence of the cerebral cortex, and this leads to qualitative functional change in the central nervous system [14].

The general functional state of the body has its own "internal pattern," or subjective experience [50]. The internal pattern of psychoemotional disinhibition is subjectively perceived as a state of "psychological comfort." And, although one observes in this state an easy flow of associations in the area of verbal production, it is not associated with actual acceleration of associative

processes and increased productivity. Even small doses of alcohol (up to 50 mℓ 40° vokda), which elicit an early euphoric effect [12], diminish productivity of sensorimotor activity, impair fine coordination of movements and increase the time of recognition of visual stimuli as a result of slowing of central cortical processes of organization of effectuating commands [15, 22, 38]. It is important to note that impairment of cognitive activity under the influence of alcohol is more marked at the resorption stage than at the stage of elimination [60], in spite of the equal concentrations of alcohol in the brain, i.e., with equal concentrations performance is more impaired in a euphoric state than in a dysphoric one.

In describing such a state of euphoric disinhibition for the purpose of its possible effects on man's professional performance, it should be noted that even under the effect of a small dose of alcohol (0.4 mg% in the blood), when inebriation is not yet present from the clinical point of view, there is a decline in drivers' skill (by 13-32%) due to imparment of somatic coordination, general disinhibition, euphoric self-overestimation and self-confident lack of concern [11, 38]. Self-overestimation is manifested with particular vividness in various forms of operator work, harboring sometimes the cause of irretrievable errors, and this is the special danger of so-called "small" doses of alcohol! This also fully applies to work related to flying professions. For example, elevated blood alcohol levels in pilots played a part in 8% of the 50,000 aircraft accidents that occurred in the United States between 1965 and 1975 [54].

Special investigations pursued to examine the effect of small doses of alcohol on flight work revealed that, under the influence of 1 g/kg alcohol, there was 4-7-fold decrease in rate of perception of visual cues, 10-20% increase in time of sensorimotor responses and almost 50% increase in localization error with interaction of vision and hearing [10]. There was also a decrease in critical fusion frequency.

The greatest decline in performance quality was observed in the first few hours after intake of 75-90 g 40° alcohol, and it was considerably more marked with increase in dose to 120-150 g [10]. The decrease in efficiency of control is referable to the resorption stage, i.e., it coincides with the period of euphoric effect of alcohol, whereas gradual restoration of work capacity is referable to the elimination stage. On the basis of these studies, it was concluded that a pilot who is even mildly intoxicated cannot cope, in a number of instances, with control of an aircraft [10]. In the wartime memoirs of A. I. Pokryshkin, he also gives a negative rating to the effect of alcohol on the combat activity of pilots, and comments, in particular, that even insignificant inebriation hinders accurate gaging of the distance to a target and accurate estimation of lead [34].

Thus, it can be seen that the state of "psychological comfort" elicited by the effect of small doses of alcohol is qualitatively different from "functional comfort." The latter is defined as the subjective sensation of the "internal signs" of a man's functional state at optimum level of activity of the body's functional systems, providing for high productivity of work with positive emotional attitude toward it [17].

The state of euphoric disinhibition is instrumental in changing communication between people, which is also one of the causes of the wide distribution of alcoholic beverages in the modern world. Man's desire for communication is a natural biological and social need. The euphoric effect of alcohol facilitates emotional contact, resulting in fuller satisfaction of the need to communicate. However, as time passes, the communication process is deformed under the influence of alcohol. At first, alcohol renders communication emotionally fuller, then, with formation of the alcoholic dominant, it becomes difficult to communicate without a drink and, finally, the need for communication disappears, the range of interests narrows down, while intake of an alcoholic beverage changes from a condition to an independent motivation of behavior [4]. Onset of a dominant pathological alcohol requirement also leads to change in range and nature of activities. Yet it is expressly activity aimed at satisfying material and spiritual needs of man that is the source of the strongest emotions. However, in drunks, the biologically determined desire to enhance positive emotions is not manifested by a search and diversity of socially relevant activities, on the contrary, the latter is limited in favor of activity to obtain alcohol. The desire to maximize positive emotions artificially by means of the euphoric effect of alcohol is dangerous and has no future. The rapidly appearing alcoholic dominant removes and replaces former material and spiritual needs, leads to reduction of socially useful forms of activity and, ultimately, to degradation of the personality.

What then must be done to successfully counteract development of a pathological addiction to alcohol, to effectively treat alcoholism and rehabilitate profesionnaly individuals suffering from this disease?

Proceeding from the conception of G. N. Kryzhanovskiy [25], the pathogenetic basis of various neuropathological states is a pathological system that emerges on the basis of a physiological system, but differs from the latter in that the results of its activities are of deadaptive, rather than adaptive, significance to the body. Appearance of a pathological system is induced by a hyperactive determinant structure or pathological determinant, am important feature of which is that it is not under systemic or intersystemic control, which is why the entire pathological system is not under integrative control. The generator of pathologically enhanced excitation, which is a population of neurons that functions like a relatively self-contained structure due to insufficiency of inhibitory mechanisms and hyperactivity of positive associations, constitutes the working part of the hyperactive determinant structure. Having once appeared, the pathological system has its own mechanisms that stabilize it, develop aggressive properties against the central nervous system, as well as resistance to therapy, which increases as the system develops.

The functional organization of the central nervous system is such that damage to any of its structures inevitably leads to disinhibition of another, leading to appearance of generators of excitation in the corresponding parts of the brain. Formation of generators of excitation is therefore viewed as a universal patbogenetic mechanism, which appears in the presence of various forms of damage to the central nervous system [25].

Since the narcotic effect of alcohol is related to its deleterious influence on inhibitory functions of the cerebral cortex, this leads to formation of a

generator of excitation in subcortical regions related to formation of emotions. For this reaspon, neurofunctional physiological systems of positive and negative reinforcement can play the role of determinant structure in formation of a pathological system with development of alcoholism. Their special significance to brain functions and those of the body as a whole, as a special system for assessing the biological significance of stimuli, is what apparently determines the amazing resistance of the pathological system formed on their basis.

In the light of the above-described conception, the problem of treating alcoholism is a problem of treating the pathological system, while pathogenetic therapy is, from the above vantage points, consists of directing action to eradicate the pathological system by suppressing it through activation of naturally occurring mechanisms and creating on their basis functionally antagonistic "antisystems" [25]. It is expressly by producing and maintaining the persistent activity of antagonistic antisystems that one can effectively counteract the alcoholic pathological system. Inclusion in the antisystem of the functional system of positive and negative reinforcement around which the pathological system was formed could lead to disintegration of the latter and restoration of stable health.

This conception of the mechanisms of development of pathological alcohol addiction and methods of enhancing the efficacy of preventive and therapeutic measures based on the systems approach is corroborated by the rather encouraging results obtained with use of a special program for the control of alcoholism among flight personnel, which began in the early 1970's in airline companies of the United States and Canada.

Before use of the above program, there was unconditional grounding of individuals who suffered from alcohol abuse, on the basis of prior experience that showed treatment of alcoholism was not effective [54, 65]. The prematurely dismissed pilots were given some somatic disease diagnosis so that they could collect severance pay and pensions. This deprived pilots of motivation for serious treatment, as a result of which many of them became inveterate drunkards and expired within 2-3 years after their forced retirement.

In view of the shortage of human resources and high cost of pilot training, a special program was developed to retain individuals in flight work who had a tendency toward alcohol abuse [54, 57, 65]. When dismissed in connection with alcoholism, pilots no longer were granted a pension, and this was a powerful stimulus for them, which motivated them for treatment and subsequent return to flight duty [56, 65]. It is easy to see that this provided conditions for appearance of a stable functionally antagonistic antisystem, which was constantly activated both by the threat of irreparable moral and material loss and the real possibility of retaining a prestigious professional status. As a result of highly motivated activity, the functional system of positive and negative reinforcement is eliminated by the pathological alcoholic system formed on its basis, and this is the condition for eradication of the latter.

Treatment of flight personnel in a drug-addiction center lasts 6-8 weeks. Then, in the absence of morphological changes in the central nervous system that are a mandatory cause for medical groudning of pilots, follows a period of professional rehabilitation that lasts about 4 months. When treatment is successful, a former aircraft captain is hired as a copilot after certification

by a panel of medical experts, and after 6 months he can resume his former position. The experience of United Airlines in rehabilitating pilots who were alcoholics revelaed that recurrence of the disease occurred within 3 years in only 7% of the treated cases (120). Specialists were convinced that after 2 years of abstinence the probability of recurrence does not exceed the probability of first-time alcobolism. For this reason, one can stop regular follow-up of pilots who have undergone rehabilitation after 2 years [57].

Professional rehabilitation of pilots suffering from alcoholism is definitely a difficult task. It became feasible thanks to a set of well thought-out and successive therapeutic, socio-organizational and educational measures. This required the joint efforts of medical personnel, management, representatives of the union and psychological support on the part of fellow workers, relatives and friends. But the main prerequisites were the patient's desire to be cured of the disease, his firm conviction that a cure was necessary and possible.

All this stresses the importance of the systems approach as the general guideline in elaborating and implementing integrated therapeutic and preventive measures for the control of alcoholism.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

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CONCEPT OF FUNCTIONAL STRENGTH IN THE PROBLEM OF OBJECTIVIZATION OF BIOMECHANICAL SPECIFICATIONS FOR PROTECTIVE AND RESCUE GEAR FOR AIRCRAFT CREWS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 18 Jul 86) pp 21-24

[Article by A. S. Barer and Yu. G. Konakhevich]

[English abstract from source] This paper discusses problems related to the ambiguous formulation of biomechanical requirements for the quality of protection and rescue means. In order to objectivize these requirements it is recommended to use the functional strength concept which reflects both mechanical (with specific features characteristic of biomechanical systems taken into account) and functional results of adverse effects. The paper also describes the potential use of this parameter in developing complex requirements for various programmed and contingent situations and probability aspects of the problem of evaluating protection and rescue means.

[Text] One of the most important conditions for effectiveness of protective gear for aircraft crews against adverse factors is a validated choice of specifications for such protection. The simplest formulation, to assure complete (maximum possible) protection against trauma "in all conceivable situations," is unfortunately not concrete. It is usually impossible to use it as the starting point for experimental design work, if only because a real solution is usually a compromise and must take into consideration some sort of rigid and often contradictory requirements--ergonomic, technological, operational, etc. Otherwise, the desire, for example, to be completely insured against manifestation of oxygen deficiency and decompression disorders would compel us to consider an insulating spacesuit as the only acceptable form of altitude gear. Incidentally, even in cases where the use of a spacesuit is necessary, the choice of positive pressure in it should also minimize the danger of caisson disease, but provide maximum mobility, for a soft spacesuit inflated to an "absolutely safe" pressure becomes inflexible.

The problem of a wise compromise is further complicated in developing rescue equipment, for example, ejection seats. Here, it is important to provide within a minimal period of time a velocity to the seat that is required for safe ejection. However, from the standpoint of tolerance to ejection accelerations, their magnitude and rate of build-up must be limited. It is

also desirable to shorten the time of preparing for ejection, but excessively rapid, forced change in the pilot's position could in itself become the cause of additional trauma. We could continue with such examples.

Although it is sometimes difficult to formulate the quantitative specifications to assure absence of trauma under extreme conditions, it is understandable that it is even more unacceptable to have no specifications. Paradoxical as it may appear, for passenger seats of the standard flight quality, for example, used by a number of countries, there are either no specifications at all as to strength that would consider man's tolerance, or else they are limited to values that are known to be inadequate, on the order of 8...10 G. Numerous traumas sustained due to destruction of seats in an emergency landing could apparently be avoided if the standards would take into consideration the range of strength of the human body (3-4 times higher accelerations in the horizontal plane could be considered acceptable with good immobilization).

The very idea of using parameters of mechanical strength of the human body as the basis for choosing specifications for protective and rescue equipment is rather attractive. However, in practice such an approach is often unsuitable.

It is not only a matter that experimental evaluation of the strength of living systems is difficult due to the high functional, age-related and individual variability and, if we are dealing with man, the impossibility of performing special tests in modes that present a trauma hazard, i.e., those that are the most informative. Analytical description and physical modeling of living systems also involve serious difficulties. However, the most important thing is that the classical concept of mechanical strength requires definition for biological systems.

Thus, living strcutures have the capacity (within certain limits) of self-restoration. This broadens somewhat the range of changes that can be considered reverisble. Another important distinction is that living systems can adapt to long-term or frequent exposure to factors of moderate intensity by means of both functional and morphological alteration.

Moreover, by virtue of the fact that living systems are very economical, a decrease in "customary," exgernal loads, i.e., beyond the level reinforced through evolution, inevitably leads to decrease in functional and strength capabilities of the skeletomuscular system. This means, for example, that when selecting specifications for cosmonaut landing equipment following long-term missions, one must consider the decrease in tolerance to accelerations which, in the absence of special preventive measures, could be quite significant.

Thus, when considering the mechanical strength of living systems one must bear in mind the active nature of their reactions to factors, which may be both positive and negative.

The reactions of the human body to external factors are often complex and systemic, and in some cases remote (in both place and time) effects could be more important than immediate local manifestations.

However, even if the above distinctions of mechanical reactions of living systems are taken into consideration, it is by far not always that we can limit

ourselves to consideration of mechanical strenghth alone (as a rule, only in cases when the exposure factor is far from vital centers of the body). For factors localized in the region of the head or trunk, or else that affect the body as a whole, of course such an approach is unacceptable.

In essence, when selecting requirements of quality of man's protection against deleterious factors, it would be more correct to refer to "functional" rather than mechanical strength of the body. From this point of view, the quality of protection should be deemed unsatisfactory if there are significant mechanical injuries, significant functional disturbances, or a combination of such effects. It must be determined just what should be construed by the term, significant. For example, with consideration of distinctions of professional work, it was previously suggested [1] that the quality of pilot or cosmonaut protection against a blow to the head is satisfactory in the following cases: if consciousness immediately after trauma is at a sufficient level to perform self-rescue operations; if it is determined that survival for 2-3 days in a deserted area is possible; if social and professional rehabilitation is achieved after specialized treatment. Such an approach may also be useful in other cases.

It should be borne in mind that most modern protective and rescue equipment, which performs its "main" functions only under extreme or accident conditions, is also an element of the operator's gear or workplace, i.e., it is also used under "normal" conditions. Since the specifications for regular and emergency parameters differ appreciably, and sometimes they are even contradictory (for example, the bearing surfaces of a seat that are optimum from the standpoint of comfort, may turn out to be excessively pliable during ejection), it is desirable to examine them as a whole.

For example, one can adopt as a requirement for the first level of functional strength the objective of providing comfort and utmost efficiency under regular working conditions. Then the task of assuring safety from trauma in an emergency situation should be logically viewed as a requirement referable to the second level of functional strength.

In conclusion, let us discuss the probabilistic aspect of the problem. Broad introduction in professional work of more and more new equipment not only failed to lower the level of "technical" traumatism in the last decades, in spite of the enormous importance attributed to the reliability of such equipment, but (according to some data) it is even rising. For this reason, it is particularly important to have a validated evaluation of the permissible level of exposure to various adverse factors. However, it was found to be basically impossible to set an "absolutely safe" value for many of them, since any actual value signifies, in essence, that there is a probability of trauma, although it is low, but not a zero probability.

Considering the exceptionally wide variability of properties of living systems, in biomechanics one limits oneself usually to a confidence level of 0.95 (less often 0.90 or 0.99). One can establish the level of a factor that is safe with a probability of more than 0.95 only with a wide scatter. If we direct ourselves to the bottom range of this scatter, we would have to artificially exaggerate the specifications for protective equipment to an unrealistic range or narrow excessively the range of application of such equipment.

Perhaps it would be more correct to limit the forecast of tolerance to the actually reachable probability level (for example, 0.95), and then assess the overall reliability of a given piece of equipment, with consideration not only of the quality of protection but extent of its use, expected modes of use, probability of an accident and different combinations of adverse factors. It can be assumed that such a method of assessing reliability and, if necessary, of searching for reserves to enhance it (of course, together with designers, specialists in operation, etc.) would be more productive. Nor can we rule out the possibility that, for some extremely unlikely combinations of emergency conditions, it will be virtually impossible to assure not only comfort and work capacity, but safety from trauma. In this case, considering the probability factor, we can limit ourselves to the requirement that life be saved, i.e., the third level of functional strength.

Thus, the following is deemed desirable for purposes of objectivization of specifications for protective and rescue gear, in particular, gear to be used in aviation and cosmonautics:

In assessing mechanical strength of the human body, consideration should be given to the active and systemic nature of his reactions to exogenous factors.

The range of using ratings of purely mechanical strength should be limited to instances when the factor is local and does not have a significant effect on basic functional systems of the body.

In other instances, one should use the concept of "functional strength," which takes into consideration both mechanical and functional consequences.

Preservation of comfort and work capacity under regular conditions should be viewed as the first level of functional strength; assurance of self-rescue from an emergency situation, survival in a deserted area, social and professional rehability should be considered the second level, and preservation of life as the third.

In making an assessment of probability of tolerance, one should limit oneself to a realistic level that can be reached in biomechanical studies (for example, 0.95).

Overall evaluation of reliability of protective and rescue gear should be made with consideration of the technical and operational parameters of the unit, as part of which the gear is to be used.

Some of the theses discussed hear are quite obvious, and they are already in use; others, perhaps require definition or change (as, incidentally, does the term "functional strength" itself). Nevertheless, it is deemed purposeful to offer them as a subject of discussion with specialists in this field in order to elaborate a validated and integrated approach to the problem of objectivization of biomechanical specifications for protective and rescue equipment.

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PSYCHOLOGICAL CONTROL OF HEALTH STATUS DURING LONG-TERM EXPOSURE TO LONGITUDINAL ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 3 Jun 86) pp 24-27

[Article by V. A. Ponomarenko, A. A. Obcznov and D. Yu. Arkhangelskiy]

[English abstract from source] It has been demonstrated by centrifugation studies that from the psychological point of view operator's activities when exposed to acceleration are complex and require continuous mental regulation of the health state. During exposure to acceleration it is important to develop in the operator a specific mental property--the skill to distributed attention between operator's tasks to be solved and mental regulation of his own health state.

[Text] Experimental data have been accumulated to data which are indicative of the influence of longitudinal accelerations on operator efficiency [1, 2, 4, 6, 8, 9 and others]. As we know, maintaining a high degree of efficiency in an altered gravity field depends on stability of professional skills, as well as the operator's tolerance to accelerations [3, 7]. Analysis of the literature indicates that primarily physical (magnitude and rate of build-up, direction of vector of accelerations) and physiological (health status, age and conditioning of operators) factors of work capacity are submitted to special investigation as related to exposure to accelerations, whereas psychological aspects proper are not studied sufficiently.

Our objective here was to disclose the psychological distinctions of operator performance with exposure to longitudinal +Gz accelerations.

Methods

Tests using +Gz accelerations of 5 and 8 G lasting 30 s each were performed on a centrifuge with the subjects wearing a G suit. The operators' task was to detect a visual marker with angular dimension of 48', which was presented 10 times in random order in 1 of 4 quadrants of an electronic indicator. They responded using two buttons situated under the left hand; upon appearance of the marker in the left quadrants of the display, the operator depressed the button under his middle finger and if it appeared in the right quadrants, he did so with the button under his index finger. Before starting the

actual tests, a firm skill was developed in all operators under ordinary conditions (without exposure to accelerations) in solving detection problems without mistakes. For this reason, the time of detection of the marker (T_{det}, baseline measurement of T_{det} was made in the centrifuge cabin just prior to the start of rotation) served as the criterion of operator efficiency. Immediately after exposure to accelerations, the operators rated the extent of impairment of their visual perception and motor functions during the period of rotation, as compared to ordinary conditions. The ratings were given on a 4-point scale: no changes, somewhat worse, worse, considerably worse. In addition, after rotation the operators answered a questionnaire, the basic purpose of which was to determine the content of their voluntary attention when performing detection tasks under baseline conditions and with exposure to accelerations. The operators of the main subgroup (4 people), who had not been exposed to accelerations previously, learned "protective" muscular and respiratory maneuvers during preliminary centrifuge rotation, which were the main physiological means of preventing visual disturbances with accelerations [5]. The subjects in this subgroup participated in 2 tests, which were performed at a 2-month interval. During the period between series, they participated in tests using +Gz accelerations in order to perform tasks involving determination of responses to a moving object and discrete compensatory tracking. The operators in the control subgroup (2 people) had much experience in solving sensorimotor problems of the continuous compensatory tracking type during exposure to longitudinal accelerations, and they had mastered protective muscular and respiratory maneuvers.

Results and Discussion

In the first series of tests, we observed a statistically reliable increase in T_{det} in all operators of the main subgroup starting at +Gz = 8 (at 5 G for operator D.), as compared to baseline values (Table 1). In the second series, we observed a tendency that was common to all operators in the main subgroup toward reduction of T_{det} under both baseline conditions and with accelerations. The most significant reduction of this parameter (by a mean of 21%) was observed with exposure to 8 G accelerations. Reduction of T_{det} in the second series of tests cannot be attributed to the conditioning factor, since the operators performed different tasks in the period between the two series. This tendency can be attributed to other factors: decrease in emotional tension in the second series, as well as inculcation and refinement of "defense" maneuvers that compensated the adverse effect of longitudinal accelerations on human work capacity. The reduction of T_{det} under baseline conditions is apparently due to the influence of the first factor and during exposure to accelerations, due to both factors.

Let us discuss the findings from a different point of view. Analysis of the results of the second series enables us to detect an important factor: there was no statistically reliable difference in T_{det} in 3 operators out of 4 during exposure to 8 G accelerations, as compared to baseline data. Consequently, unlike the first series, accelerations cease to have a negative effect on T_{det} in the second series (see Table 1, A). Let us assume that, in the first series, statistically reliable increase in T_{det} under the effect of accelerations is due to marked worsening of visual perception of signals and/or difficulties with the motor component of the response. Conversely, in the second series, due to increased tolerance to accelerations,

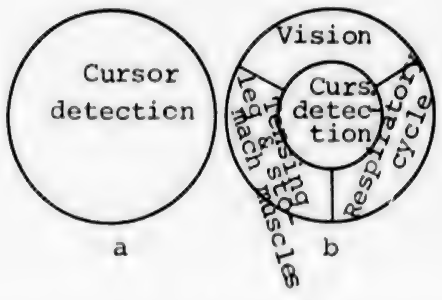
Table 1. Time of detection of cursor by operators in the main (A) and control (B) subgroups as a function of magnitude of +Gz accelerations (M±m)

Subgroup of subjects	Series	Baseline [BL]	$+G_z$		p (BL - Gz = 8 G)
			5	8	
A:					
D.	I	378±15	456±16	495±44	<0,05
	II	358±12	340±7	361±29	>0,05
Ye.	I	349±11	344±12	401±19	<0,05
	II	302±7	298±17	318±16	>0,05
S.	I	298±11	333±26	368±16	<0,01
	II	261±9	330±16	308±28	>0,05
M.	I	322±14	373±34	455±48	<0,05
	II	282±10	353±28	385±22	<0,01
B:					
G.		324±13	346±28	378±34	>0,05
Z.		295±10	286±11	284±38	>0,05

such visual disturbances and/or difficulties in responses disappear. However, analysis of subjective evaluations of the operators did not confirm this assumption. According to the data listed in Table 2, the operators failed to observe significant worsening of visual perception and difficulties in response reactions in either the first or second series of tests. The absence of marked visual disturbances with exposure to accelerations of up to 8 G is attributable, to a significant extent, to the operators' use of "protective" procedures, as well as wearing a G suit. At the same time, constant direction of voluntary attention is required of operators to maintain the required muscle tension and respiratory maneuvers with exposure to accelerations. This is indicated by the answers to the questionnaire. Thus, under baseline conditions, the operators' voluntary attention is concentrated exclusively on performing the task of detecting the cursor. With exposure to accelerations, even the most experienced operators must also devote attention to checking integrity of their visual perception, level of tension of leg and abdominal muscles and regulation of respiratory cycles (see Figure). In other words, voluntary control of their status becomes an independent task for the operators, which they perform concurrently with the basic task of detecting the cursor. It can be considered that, in the first series of tests, the operators in the main subgroup do not yet have the ability to distribute attention for simultaneously solving both problems, although they had learned to solve each of them separately. Judging by the fact that, in the first series, exposure to accelerations leads to statistically reliable increase in T_{det}, the operators concentrate mainly on controlling their status to the detriment of the task of detecting the cursor. In the second series, exposure to analogous levels of accelerations does not lead to reduction in cursor detection time, and for this reason it is quite mustified to conclude that the operators had acquired the ability (with the exception of one individual) to properly distribute their attention. When is this ability formed? Apparently only during rotation in theintervals between the first and second series of tests. Interestingly, we encounter here the phenomenon of transfer of this skill, since the task for the operators during rotation in the intervals between

Table 2. Subjective ratings of operators in main subgroup (+Gz = 8 G)

Operator	Series	Condition of vision	Condition of muscles
D.	I	No changes	No changes
	II	Somewhat worse	" "
Ye.	I	Same	" "
	II	No changes	" "
S.	I	" "	" "
	II	" "	" "
M.	I	Somewhat worse	" "
	II	Same	" "



Direction of voluntary attention of operators while performing task of cursor detection
a) baseline period
b) exposure to accelerations

series was not to detect the cursor, but to perform other sensorimotor tasks. The transfer effect is also indicated by the findings for operators in the control subgroup. These individuals, who had much experience in compensatory tracking with exposure to accelerations were faced with a detection task for the first time. Nevertheless, they immediately detected the cursor just as rapidly as under baseline conditions (see Table 1). Evidently, this effect can also be attributed to positive transfer of previously acquired ability to correctly distribute their attention among simultaneou performance of compensatory tracking and constant checking of their state in solving the task of cursor detection, which was relatively new to them. It should be stressed that such monitoring remains deliberate, even in the best trained operators who have good tolerance to accelerations. This is proven by the instances of premature stopping of the centrifuge due to development of visual disturbances, which were observed in the interseries rotations. Such disturbances arise when operators, while concentrating their voluntary attention exclusively on performance of the sensorimotor task, lose control over their state.

Thus, the results of this investigation warrant the belief that, from the psychological point of view, operator work during exposure to accelerations is combined, and it requires that the operator be able to distribute his attention among simultaneous performance of several highly motivated tasks: actual operator task, constant voluntary monitoring of his condition, performance of "protective" muscular and respiratory maneuvers. Neither acquisition of skill in protective muscular and respiratory maneuvers nor presence of solid professional skills per se do not generate such ability, although they are prerequisites for it. Purposeful formation of a special psychological trait--ability to distribute attention among performance of operator tasks,

monitoring and correcting his condition--must become an important element in the psychological training of an operator for successful professional performance during exposure to accelerations.

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THEORETICAL ANALYSIS OF EFFICACY OF G SUITS WITH EXPOSURE TO CONTINUOUSLY INCREASING ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 19 Jun 86) pp 27-33

[Article by B. L. Palets, M. A. Tikhonov, A. A. Popov, D. Yu. Arkhangelskiy, L. D. Palets and R. A. Bondarenko]

[English abstract from source] A mathematical model of human circulation was employed to examine circulation responses to +Gz acceleration the value of which increased linearly at the rate 0.1 G/sec, using subjects having an anti-G suit on and sitting in a relaxed posture. It has been calculated that the anti-G suit can compensate as much as 83% of the increment of hydrostatic pressure in leg vessels and as much as 57% in abdominal vessels. The suit effect on resistance and capacity vessel properties makes an approximately equal contribution to an increase of the acceleration tolerance threshold. However, the occlusion effect of the anti-G suit causes a significant increase of afterload.

[Text] Development and determination of efficacy of various means of limiting the adverse effect of accelerations on human circulation are among the principal tasks of aviation medicine [2]. As shown previously [6], even the use of the most simplified theoretical schemes helps gain better understanding of hemodynamic regulation under such conditions. However, a more detailed analysis of the correlation between physiological and biophysical reactions that occur under the effect of hypergravity and use of antigravity gear (AGG) is possible only with the use of complex simulation models.

Our objective here was to use the previously published mathematical model of human circulation [4] to analyze the effects of a G-suit (GS) and positive pressure breathing (PP) during exposure to +Gz accelerations increasing linearly at the rate of 0.1 G/s with the subject seated in relaxed position, with his trunk tilted 60° in relation to the horizontal plane.

Figure 1 illustrates an enlarged flowchart of the model of human circulation. The proposed model reflects the correlation between biophysical, self-regulatory and reflex regulatory processes in a ramidifed hemodynamic circuit with consideration of the effect of variable gravity.

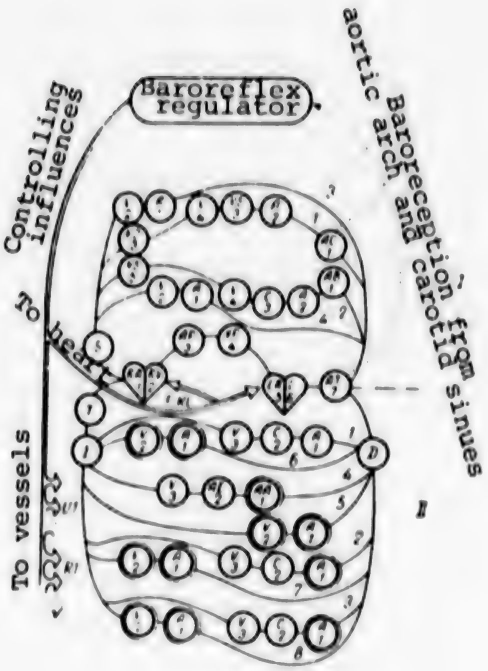

Figure 1.
Diagram of circulation model

A) arteries
AA) afferent renal arterioles
AC) sinocarotid arteries
AE) efferent renal arterioles
AB) brachial arteries
AP) pulmonary arteries
AT) thoracic aorta
C) capillaries
D) abdominal aorta
F) heart rate
I) abdominal part of inferior vena cava
KL) inotropic coefficient of the heart
LA) left atrium
LV) left ventricle of the heart
RA) right atrium
RV) right ventricle
RI) resistance of arteries
S) superior vena cava
T) thoracic part of inferior vena cava
UI) relaxed venous volume
V) veins
VI) jugular vein
VP) pulmonary veins
VS) subclavian vein
I) top part of the body
1-4) vessels of the brain, arm muscles, scalp and arm skin, respectively
II) bottom part of the body
1-3) vessels of musscles of the trunk, thighs and crus, respectively
4) renal vessels
5) abdominal organ vessels
6-8) cutaneous vessels of the trunk, thighs and legs, respectively

← Numerals on the lines refer to indexes for branches of the vascular system. Numerals within circles refer to indexes for segments in vascular system branches. Double circles indicate segments with controllable resistance (RI) or relaxed vascular volumes (UI).

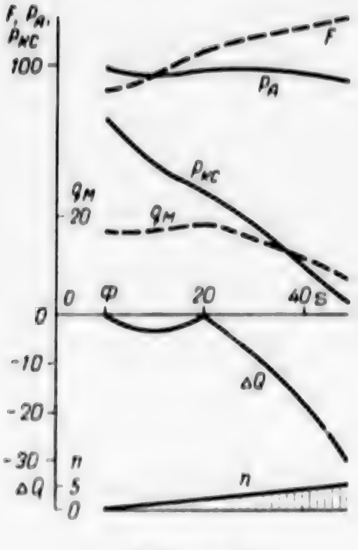

Figure 2.

Dynamics of human circulatory parameters with exposure to linearly increasing accelerations in head-pelvis direction without AGG

Studies conducted on mathematical model. Here and in Figures 3-6:

P_A, P_{KC}) mean pressure in aorta and carotid sinus, respectively (mm Hg)
F) heart rate (per min)
g_M) influx of blood to the brain (cm^3/s)
ΔQ) deviation of circulation volume from baseline (Φ, %)
n) acceleration parameter (G)
t) time (in seconds)

GS effects were simulated in a model of elevated external pressure (p_{ei}) over vessels of the lower half of the body (muscles and skin of the trunk and limbs, abdominal organs), as well as increased hemodynamic resistance in these regions (R_i) due to their compression (occlusion) proportionate to the level of external pressure applied.

$$R_i = R_{0i}(1 + p_{ei}/p_{mi}),$$

where p_{mi} is the coefficient of approximation.

PP effect was produced by raising external pressure (p_e) to the vessels of the lungs, heart chambers and great vessels situated in the pleural cavity, which is equivalent to reduction of relaxed volumes in these regions (u_i) as determined by the formula:

$$u_i = u_{0i} - Kp_e/d_i,$$

where u_{0i} is the baseline value of u_i, K is the coefficient of transmission of PP to vessels and d_i is the parameter characterizing rigidity of vessels.

The mathematical model was tested on a BESM-6 digital computer.

Results and Discussion

Figure 2 illustrates the plots for change in hemodynamic parameters with increasing accelerations, without use of AGG. Adequacy of the model to the results of tests on man according to parameters of systemic hemodynamics under such conditions was demonstrated previously [4].

The response to accelerations of influx of blood to the brain (g_M) is consistent with the results of experiments on animals [11]. According to [1], 5 G was the limit of tolerance to accelerations. For this reason, in the model studies we took the nominal value of 5 G for g_M as the maximum allowable level, and evaluated the efficacy of AGG according to their effect on this parameter.

As can be seen in Figure 2, arterial pressure at the level of the heart (P_A) changes insignificantly with accelerations. Accordingly, it would rise with use of GS. When a certain maximum level (P_{max}) for homeometric self-regulation of the heart is exceeded, this leads to decline in pumping function of the heart, defined as stroke volume as a function of end diastolic volume [5]. With consideration of this factor, the parameter of inotropic state of the heart (k), which determines the slope of the curve of ventricular function, is calculated using the following formulas:

$$k = k_0 + \Delta k_N + \sum_j \Delta k_j, \ j = 1, 2,$$

$$k_0 = \begin{cases} \sigma_0 - \sigma_1 (P_A - P_{max}), & P_A > P_{max} \\ \sigma_0, & P_A \leq P_{max} \end{cases}$$

where Δk_0 are changes in k under the effect of higher autonomic centers (in this study, it is a constant), Δk_j are changes in k due to a reflex from the jth reflexogenic zone, σ_0 and σ_1 are coefficients of approximation found from the results of experimental studies [5].

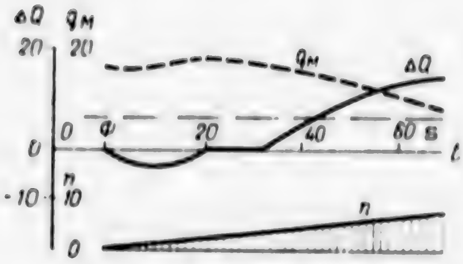

Figure 3.
Circulatory reaction to accelerations and simulation of effect of GS that compensates entirely for increment of hydrostatic pressure in vessels of the lower half of the body

Dot-dash line indicates level of blood delivered to the brain corresponding to maximum tolerance, which constitutes g_M of 5 G without the GS.

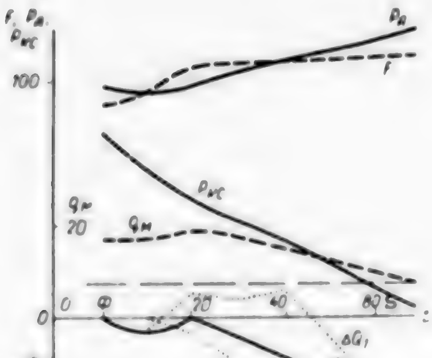

Figure 4.
Dynamics of human circulation with exposure to accelerations and use of GS

ΔQ_1 and ΔQ_2 are deviations of circulation volume according to results of tests on humans [6], respectively [sic] [translator's note: obvious omission in this phrase]

According to data from the model, the mean increment of hydrostatic pressure (Δp_g) constituted 24 mm Hg per G acceleration in the legs and 14 mm Hg in abdominal organs. The first model experiment consisted of simulating the effect of a GS would entirely compensate for the increment of hydrostatic pressure starting at accelerations of 2 G ($\Delta p_{ei} = \Delta p_g$).

A comparison of model estimates (Figure 3) and results of tests on humans [1, 6] revealed that with this version of the effect of a GS cardiac output is substantially greater than in actuality, although there is insignificant difference in range of tolerance to accelerations. Hence, compensation of pressure rise with use of the GS is not complete ($\Delta p_{ei} < \Delta p_g$), and the GS has an effect on vessels that leads to change in distribution of circulation volume causing relative increase in delivery of blood to the upper half of the body, in particular the brain. Our subsequent studies dealt with quantitative analysis of these factors.

The purpose of the second model experiment was to select Δp_{ei} and parameters determining the effect of the GS on resistance of vessels (p_{mi}) in such a way as to have quantitative conformity of the model to the object. Rather realistic modeling results were obtained with Δp_{ei} of 20 mm Hg for the legs and 8 mm Hg for the abdominal cavity and with p_{mi} of 200 mm Hg (Figure 4). For these vascular regions, the coefficients of efficacy ($K_э = \Delta p_{ei}/\Delta p_g$) constituted 0.83 and 0.57. These figures are close to those obtained for coefficients of transmission of pressure obtained in tests on humans, which were calculated as the ratio of pressure increment in the GS and rectum, although the actual changes in pressure differed appreciably. Thus, experimental evaluation of coefficients of transmission reflect correctly the share of Δp_g compensated by the GS. It should be noted that there was considerable variation of hemodynamic reactions to accelerations with use of GS in different series of tests on humans. For this reason, to compare the

reactions of the model and object, Figure 4 illustrates the changes in cardiac output (ΔQ, %) obtained in two series of experiments [1, 6]. As can be seen in Figure 4, the ΔQ_n function in the model virtually coincides with the mid-line in both series. Judging from the estimated value for g_M, use of GS improves tolerance to accelerations from 5 to 7 G, which is also consistent with previously published data [6].

In this case the GS effect is attributable to both relative increase in central blood volume and cardiac output, as well as redistribution of blood flow into the upper part of the body, primarily into cerebral vessels. We estimated the relative contribution of these two factors to increase in tolerance to accelerations. The results of calculations revealed that both factors are about equivalent in their effect on cerebral blood flow. Thus, in our case, the occlusive effect of the GS does not play a smaller part than partial equilibration of Δp_g by means of affecting the capacitive characteristics of vessels.

However, we should call attention to the results of modeling that revealed a significant elevation of mean pressure in the aorta (P_A) with use of the GS during accelerations. According to our estimates, P_A rises by about 20% at maximum tolerance (7 G), as compared to baseline values. The following circumstance is also important. The proposed model reflects the relationship between mean values for hemodynamic parameters. However, the observed elevation of mean blood pressure could be achieved with different combinations of diastolic (P_∂) and systolic pressure. Obviously, in the presence of increased peripheral vascular resistance, due to the occlusive effect of the GS, diminished systolic ejection and increased heart rate, there is a more significant elevation of P_∂ than P_A. In turn, elevation of P_∂ produces an additional load on the heart during the period of development of tension. As shown by a number of researchers [7, 8], there is a considerably greater (by several times) cost with respect to oxygen of energy expended by the heart in the phase of isometric contraction than in the ejection phase. Consequently, use of a GS in the case in question could involve an excessive load on the heart. It can be concluded from the model studies that a GS, the structure of action of which is determined more by compensation of the increment of hydrostatic pressure and less by occlusion of vessels, is physiologically more adequate.

There is one distinction to use of positive breathing pressure in aerospace medicine. The same factor, which leads to displacement of a certain volume of blood from the central regions of the heart and lungs to the periphery, is used also to simulate the effect of gravity on hemodynamics, for example in tests with head-down tilt [3] and to prevent the adverse effect of hypergravity on blood supply in the body [6, 9], i.e., to achive goals that are opposite to some extent. Apparenlty, the efficacy of PP will depend on the specific conditions under which it is used.

A mathematical model was used to test the efficacy of PP during accelerations with and without the use of a GS. The PP mode consisted of raising p_e by 5 mm Hg/G starting at 2 G.

Figure 5 illustrates the dynamics of circulatory reactions to +Gz accelerations during positive pressure and normal pressure breathing without use of GS. As can be seen from the curves, use of PP in this case virtually fails to increase circulation volume and cerebral blood flow at comparable G levels. Accordingly,

there was also no increase in tolerance to accelerations. Special mention should be made of the fact that g_m does not increase, in spite of the noticeable elevation of arterial pressure on the level of the carotid sinuses (P_{KC}). This is due to the fact that elevation of pressure in the pleural cavity cannot in itself increase either systemic or regional blood flow, since there is the same increment in both arterial and central venous pressure. Consequently, use of P_{KC} as a criterion of adequate cerebral blood supply is unwarranted if PP is used.

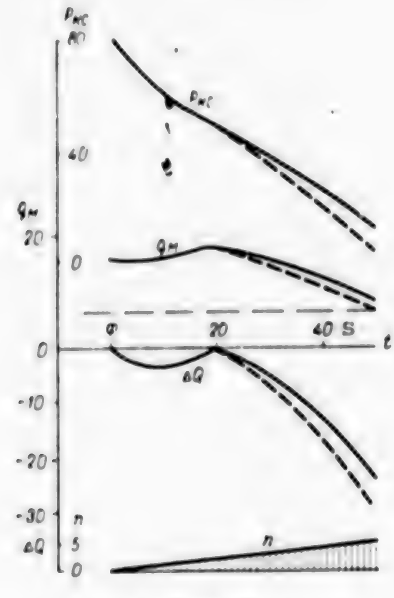

Figure 5.
Reaction of human circulation to accelerations in head-pelvis direction under ordinary breathing conditions (dash line) and with positive pressure breathing (boldface line) without use of GS

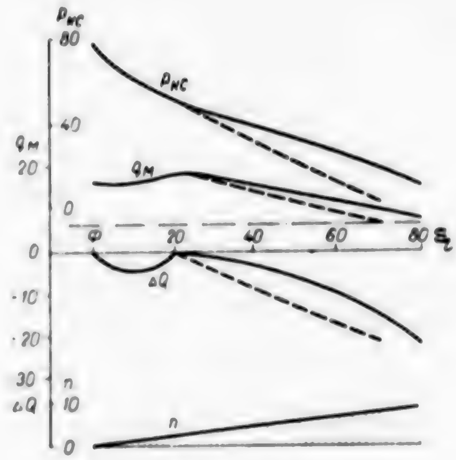

Figure 6.
Dynamics of human circulation during positive pressure breathing with use of GS

In theory, the beneficial effect of PP on systemic and regional circulation may be attributable to two causes. The first is redistribution of blood in the lungs in a vertical direction, maintenance for this reason of a higher gravity gradient of the heart-lungs and, accordingly, increased efflux of blood from the lungs--cardiac output. It should also be borne in mind that these conditions of linearly increasing accelerations are transient, and the values for Q illustrated in Figure 5 are considerably greater than overall venous return. As was shown previously [4], this factor has an appreciable influence on blood supply of the body and range of tolerance to accelerations. Consequently, the greater the effect PP has on the dynamics of efflux of blood from organs of the pleural quality, the greater its beneficial effect. The second cause of the PP effect may be decrease in resistance of cerebral vessels due to their being strentched by the additional volume of blood shifted from the central region. However, in the situation discussed above, the role of both factors is insignificant, since venous return to the heart and, consequently, central blood volume are significantly diminished, while redistribution of volumes and blood flow occurs mainly into the lower part of the body.

Hemodynamic reactions are different in the case of PP with use of a GS. As can be seen in Figure 6, with the same accelerations PP leads to noticeable increase in circulation volume and cerebral blood flow, as well as appreciable elevation of pressure in the region of the carotid sinuses. As a result, the range of tolerance to accelerations increases to 8 G. The results obtained with the model conform with data obtained from tests on humans [6].

The following are the causes of the positive effect of PP with use of GS: greater influx of blood to the heart (according to model data, central venous pressure at 5 G is 1.3 mm Hg higher with GS than without it), as well as the fact that the increase in circulation volume is directed primarily to the upper part of the body, primarily cerebral vessels, thanks to the occlusive effect of the GS. Accordingly, the pressure of the GS applied also to the upper part of the body elicits some additional effect, increasing somewhat the range of tolerance. Thus, the results of model calculations conform to experimentally derived conclusions to the effect that a GS must be used to elicit an effect from PP, and they enable us to make a quantitative analysis of both antigravity factors in their interaction.

As shown above, the effect of the GS under ordinary conditions is attributable to its influence on both vessel capacity and resistance. This leads to substantial worsening of delivery of blood to the lower half of the body. According to data obtained with the model, at 8 G the influx of blood decreases by 16.5 and 63% to organs of the abdominal cavity and leg muscles, respectively. At the same time, estimates have shown that, with use of PP, the relative contribution of the occlusive effect of the GS to tolerance to accelerations is relatively smaller than under ordinary breathing conditions. Thus, if we assume that the compensation for increment of hydrostatic pressure can be increased by 10-12%, the same range of tolerance to accelerations of g_m can be obtained with less (by one-half) occlusion of vessels of the lower half of the body. Delivery of blood to the corresponding regions would be retained at close to the baseline level. Thus, use of PP expands, from the physiological point of view, the possibilities of improving GS. According to model data, PP does not lead to appreciable changes in arterial pressure on the level of the heart, in spite of significant elevation of P_{KC}. Herein, no doubt, lies the advantage of the method, since it enhances tolerance to accelerations without increasing the resistance load on the heart.

Efforts to further expand the range of tolerance to accelerations by any of the known methods, with the exception of the commonplace one (reduction of angle of inclination of the trunk in relation to the horizontal plane) inevitably lead to further elevation of P_A. There is one more important circumstance to be considered, in addition to the previously mentioned adverse aspects of augmenting the arterial load on the heart in the presence of accelerations, with use of GS.

Rise of arterial pressure in itself is a factor that limits circulation volume and, consequently, delivery of blood to the brain. Cardiac output is a rather complex function of counterpressure in the aorta, which differs substantially in transitory and established modes. As has been shown [5, 10], Q is virtually independent of P_A over a wide range of changes in the latter, when conditions are established, and this is a manifestation of homeometric self-regulation of the heart. This type of self-regulation has an inertial period

of 1-2 min, and in a transitory mode elevation of P_A leads to transient decline of cardiac output. The better the functional state of the heart and its contractility, the shorter the duration of the transitory press and the less marked the decline of cardiac output in this period, and the greater the maximum elevation of P_A that does not lead to decline of Q. These patterns were established on the isolated heart [5]. In the intact body, they could be obscured by processes of neuroreflex regulation. However, in the situation of accelerations in question, with use of GS the mechanism of homeometric self-regulation apparently plays a substantial role, primarily because reflexes in the heart from the two basic reflexogenic zones (aortic and sinocarotid) counteract one another. It appears probable that these processes are ultimately the factor that limits tolerance to accelerations with use of AGG.

It should be noted that one usually considers the heart to play a secondary role in reactions to accelerations, as compared to the vascular factor. The AGG in question, which simulate the constriction reactions of capacitive and resistive vessels and prevent displacement of blood to the lower part of the body, are directed toward enhancing the vascular factor. The statement that the cardiac factor plays an insignificant role in this phenomenon should be considered valid when there is a substantial decline of central blood volume and influx to the heart. However, use of AGG, which limits a pressure drop on the level of the carotid sinuses and elicits progressive elevation of arterial pressure on the level of the heart, causes relative increase in the role of load characteristics of the heart in hemodynamic reactions to accelerations. Even if we assume that the means of further mobilization of functional reserves of vessels will be found, apparently the heart will be the limiting factor. Since the equipment apparently does not exist that would expand the functional capacities of the heart under such conditions, the range of tolerance to accelerations is determined to a significant extent (of course, only according to the criterion of adequate hemodynamics) by individual characteristics of the heart, its capacity to eject the required amount of blood in the presence of arterial pressure that is rising appreciably and rather rapidly. As soon as a quantitative parameter will be found that reflects this capacity, it will have considerable value to problems of professional screening and conditioning for tolerance to the type of accelerations we have discussed here.

Thus, the proposed mathematical model adequately reflects the nature of man's circulatory reactions to accelerations in the head-pelvis direction with use of GS and positive pressure breathing. A mandatory prerequisite for efficacy of PP as an antigravity device is to have a GS that intensifies venous return to the heart. The occlusive effect of the GS with PP is of secondary importance. The range of tolerance to accelerations with use of AGG is determined to a considerable extent by sensitivity of cardiac output to elevation of blood pressure.

The distinction of our study is that a mathematical model was used to analyze the results of concrete investigations. Thus far, there has been little work of this sort and, of course, our analysis of regulation of human hemodynamics in the presence of accelerations and with use of some AGG cannot be considered complete. However, the fact that with the use of a single model it was possible to obtain agreement between theoretical calculations and experimental data in rather complicated situations is indicative of accurate reflection in

the model of the basic physiological characteristics of the object. Thus, the obtained conclusions can be considered a consequence of these characteristics, rather than simplifications adopted in building the model.

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EFFECT OF LINEAR, IMPACT AND VIBRATION ACCELERATIONS ON ACCURACY OF OPERATOR IMPLEMENTATION OF STRENGTH LOAD PROGRAMS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 6 Mar 86) pp 34-37

[Article by I. N. Koroleva, S. V. Petukhov and Yu. O. Bulayev]

[English abstract from source] The factors that influence the accuracy with which motor commands are actualized were investigated. The study concentrated on linear acceleration of different sign (produced by rocking a heavy metal platform), vibration at a frequency of about 23 Hz, and impact acceleration resulting from the platform or the rotating chair being suddenly stopped. The force applied to hand sticks or foot levers was recorded by means of electromechanical sensors. It was demonstrated that smoothly varying and in particular impact acceleration caused normal men to subjectively underestimate their own muscle efforts. As a rule, this led to a greater than prescribed strength applied. It is very important to note that acceleration acting from right to left or from left to right (in the frontal plane) produced nonsymmetric pressure by the right and left limbs.

[Text] Servicing new equipment and high-speed devices requires high mobility of nervous processes in the operator, fine interaction of analyzers and, at the same time, immediate motor responses [5]. A number of operator tasks requires precise implementation of programs of strength loads in the presence of intensive vibration, dynamic and vestibular loads. It is known that vibration and impacts can lead to diverse undesirable consequences: motion sickness, spatial disorientation and vertigo, discoordination of movements, sensorimotor illusions, autonomic disturbances, etc. [1-3].

It is also known that the effect of impact and vibration factors depends on the individual's position, nature of immobilization by belts and degree of muscular tension [4]. At the same time, the nature of the effect of vibration and impact loads on performance of operator tasks, including accuracy of performance of specified programs of strength loads, remains unclear in many respects.

In view of the foregoing, the main objective of our investigation was to study the distinctions of graded muscular exertion in healthy subjects in the presence of vestibular stimulation with a variable sign, impact accelerations and combinations thereof with vibration. An additional task consisted of

testing the effect of the position of a seated man on implementation of such a program. The distinction in our studies was that the conditions of the laboratory experiment were similar to the actual situation of operator work in, for example, the cabins of many forms of vehicles.

Methods

The study was conducted on 20 healthy subjects 25 to 37 years of age who had no special operator training. The program of strength loads involved the following: 1) teaching the subjects to exert specified muscular efforts of 5 kg (49 N) alternately with the left and right leg; 2) to execute these commands in accordance with an established audio cue at the time of exposure of the subject to approximately 0.1 G linear accelerations in a frontal direction; 3) to execute these commands at the moment of exposure to impact of about 2.5 G in a frontal direction; 4) to execute these commands in accordance with an established audio cue at the time of exposure to linear accelerations of about 0.1 G in the frontal direction combined with vibration (f = 23 Hz, N = 0.3 G); 5) to execute these commands at the moment of exposure to impacts of about 2.5 G in a frontal direction combined with vibration of the above parameters.

For exposure to the above factors, a unit was used, the main part of which was a platform suspended on 4 rigid rods 2.90 cm in length. This device enabled us to generate and constantly maintain vibrations in different directions with an amplitude of 25 cm, which varied from 0 to $2.7°/s^2$ in accordance with the sinusoidal law. A chair was mounted on the platform, which was equipped with pedals for the left and right foot, and the muscular force applied to them was recorded in analogue form by means of electric dynamometers. The position of the back of the chair and support with pedals could be changed from 0 to 45° in relation to the vertical plane to provide for the required segmented position of the seated subject. Impact acceleration was produced by stopping the platform abruptly for 20 ms, during which accelerations in different directions arose at 2.5 G. Vibration was produced by means of the vibration stand mounted on the platform, which produced vibration of f = 23 Hz and N = 0.3 G. The audio signal, which served as the command to depress the left or right pedal was delivered 20 ms before maximum acceleration of the platform with the subject going from right to left in a frontal direction, or 20 ms prior to the start of impact acceleration in the same direction. The magnitude of muscular force developed by the subject for the left and right foot separately was averaged in each of the tests for at least 30 test runs.

After each series of test runs, the subject was allowed to rest for 2 min. In the course of the experiment, the motor skill developed to produce a graded muscular effort was checked periodically and, if necessary, additional training was used. An array of $7.5 \cdot 10^3$ parameters of execution of muscular efforts was submitted to analysis. The time correlations between the moment of delivery of the audio signal and moment of depressing the appropriate pedal were used to monitor reaction time and constancy of stimulation conditions.

Results and Discussion

We demonstrated that the above-mentioned factors had a reliable effect on the tested motor responses. Statistical analysis revealed that both types of

vestibular stimuli used and their combination with vibration led to increase in developed muscular exertion, as compared to baseline values; however, the pattern of these changes varied. In particular, linear vestibular stimulation elicited asymmetry of execution of motor commands to the right and left lower limbs (Figure 1): the exertion of the right foot (contralateral in relation to the direction of linear acceleration) was reliably lower than that developed by the left, homolateral, limb in 16 out of 20 subjects; in the other cases, there was either no demonstrable difference or else it was statistically unreliable. The degree of asymmetry was determined by calculating a special coefficient:

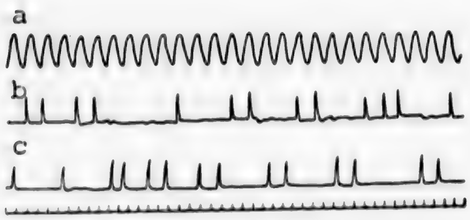

Figure 1.
Muscular exertions in the presence of linear vestibular stimulation
Here and in Figures 2 and 3:
a) movement of platform
b) depression of pedal with right foot
c) same with left foot

$$AK = \frac{Md - Ms}{Md + Ms}$$

where AK is the coefficient of asymmetry of muscular exertion, Md is mean muscular exertion applied by the right lower limb and Ms is the same for the left lower limb. The Table lists individual and mean values for the coefficient of asymmetry with exposure to different factors.

Individual and mean values of coefficient of asymmetry with different factors

Subject No	1	2	3	4	5	6	7	8
K_0	2,13	2,34	–3,19	22,76	–1,69	1,35	1,35	0,33
K_{lin}	6,82	9,54	4,85	1,16	3,64	1,82	16,3	9,76
$K_{lin+vib}$	7,19	2,0	–1,02	1,27	–1,021	7,86	5,89	8,16
Subject No	9	10	11	12	13	14	15	16
K_0	–0,29	–1,76	–3,16	2,42	–2,88	–1,65	0,87	–0,68
K_{lin}	2,19	8,08	1,11	6,51	5,79	12,19	4,59	9,78
$K_{lin+vib}$	6,02	7,22	5,58	8,36	11,21	6,39	7,41	3,26
Subject No	17	18	19	20	Mean			
K_0	–1,16	0,89	–1,26	–2,13	0,89			
K_{lin}	–1,78	8,84	6,53	4,78	6,04			
$K_{lin+vib}$	2,17	4,29	5,76	2,87	5,13			

Key: K_0) coefficient of asymmetry in baseline period, %
K_{lin}) coefficient of asymmetry with exposure to linear accelerations, %
$K_{lin+vib}$) coefficient of asymmetry with exposure to linear accelerations combined with vibration, %

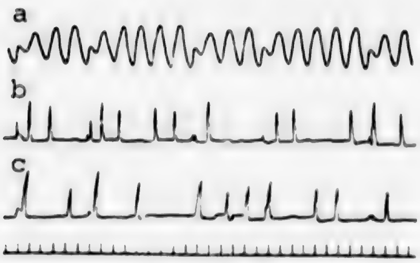

Figure 2.
Muscle exertion with exposure to impact

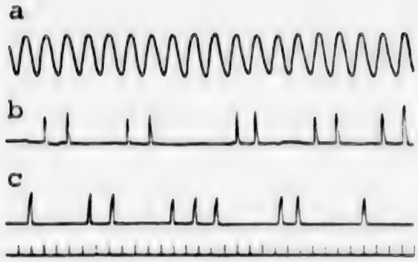

Figure 3.
Muscular exertion with exposure to vibration

In the case of impact, a statistically reliable change in precision of graded muscular effort, in the direction of exceeding the specified level, was observed in all subjects (Figure 2). Asymmetry in execution of motor commands by muscles of the right and left lower limbs was also observed in all subjects; however, considering the impact reaction time, either the first or second phase of impact had an effect; in other words, the sign of immediate acceleration changed before the command was executed. For this reason, the direction of asymmetry of developed effort also varied.

Vibration elicited insignificant increase in developed muscular exertion, as compared to the same experimental conditions without vibration (Figure 3). We were impressed by the fact that there was a more marked decrease in asymmetry of efforts made by the right and left lower extremities during the experiments (see Table), particularly with the combination of vibration and linear accelerations, and to a lesser extent, with impacts.

The posutre of seated man has a very definite effect on precision of executing specified programs of strength loads. When the torso is bent back from the vertical plane at an angle of 15°, 30° and 45°, 17 out of 20 subjects showed reliably greater precision of developed muscular exertion at a 30° angle than at 15 and 45°. Our results are consistent with the data of N. I. Karpova [4]. In this position, the increment of mean absolute pressure to the pedal was considerably less marked, as compared to the baseline. There was also less marked asymmetry of motor responses of the right and left limbs during vestibular stimulation. Mean values for the coefficient of asymmetry were 7.85% in a 15° position, 4.11% at 30° and 6.03% at 45°.

Thus, when working on optimization of working conditions and operator training, one should take into consideration the fact that smoothly changing or impact vestibular stimulation consistently elicits impairment of subjective perception of strength of exertion developed by muscles in the direction of their underestimation. This results in exceeding the specified intensity of strength loads. It should also be noted that vestibular factors, the vector of which is in a frontal direction, elicit an asymmetrical muscular reaction in most healthy subjects, in the form of exceeding the muscular exertion generated by the homolateral limb, as compared to that of the contralateral limb.

Sitting with the trunk tilted 30° back from the vertical plane is the optimum position, since the above-listed differences from baseline values are then the least marked. Vibration with intensity of 0.3 G and f = 23 Hz has an insignificant effect on accuracy of operator execution of given programs of strength loads in the presence of vestibular stimulation. At the same time, such vibration elicits, in most subjects, a decrease in asymmetry between reactions of the right and left lower limbs, which arises under the influence of vestibular stimulation.

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ADAPTIVE AND CUMULATIVE EFFECTS ON DOGS OF REGULAR EXPOSURE TO +Gz ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 14 May 86) pp 37-40

[Article by R. A. Vartbaronov, G. D. Glod, N. N. Uglova, I. S. Rolik, I. G. Krasnykh, V. G. Novikov and N. A. Gaydamakin]

[English abstract from source] The development of adaptive and cumulative effects was investigated in 13 noninbred dogs regularly exposed to +Gz acceleration: Group I dogs were exposed 3 to 4 times a week for 2 months and Group II dogs were exposed 1 to 2 times a week for 5 months. The tolerance threshold was evaluated with respect to ECG abnormalities. The study of circulation reactions and acceleration tolerance threshold revealed the predominant development of adaptive changes that were more distinct in Group II dogs. Cumulative effects in the form of functional disorders of pulmonary vessels occurred in all experimental dogs, but less frequently in Group II dogs. Morphological lesions of the lung tissue developed in Group I animals after 2 to 3 exposures and in Group II animals after 2 to 3 months, the incidence rate being lower in those latter. These findings suggest that adaptive and cumulative effects in response to regular exposures to threshold +Gz acceleration develop more or less in parallel.

[Text] It is known that animals sometimes develop adaptive changes combined with cumulative effects as a result of repeated exposure to accelerations. There is information in several works [1, 2, 3, 10, 11] about the nature of cumulative effects, which were assessed according to biochemical and hormonal changes, as well as pathomorphological changes, and to the effect that their appearance is a function of intensity of accelerations and frequency of exposure to them. In particular, it is reported in one of the studies [12] that no pathological changes were observed in different organs of dogs and monkeys after 3-4-h exposure to +Gz accelerations ranging from 3 to 6 G and lasting 5 to 15 s. In another study [14], it was shown that daily exposure to accelerations of 8 to 12 G lasting up to 15 s for 26 days did not elicit any cumulative effects in dogs. With increase in duration of individual accelerations to 2 min, pathological effects were observed that were similar to those reported previously [3, 6, 11, 12].

Our objective here was to investigate the share of adaptive and cumulative effects on intact dogs of regular exposure to maximum tolerable +Gz accelerations repeated for different numbers of times.

Methods

Experiments were performed on a centrifuge with a 4.5-m arm using head-pelvis accelerations. The study was conducted on 13 intact, adult, mongrel dogs weighing 7-10 kg. The methods of immobilizing the animals on the centrifuge and their preparation for long-term experiments were described previously [1]. We conducted two series of tests using accelerations with a profile (Figure 1a) of increasing intensity. In the 1st series (6 dogs), which lasted 2 months, animals were exposed to this factor 2-3 times a day, twice a week (Figure 1b). In the 2d series (7 dogs), lasting 5 months, frequency of exposure was one-third of that in the 1st series, while total number of exposures was close to that of the 1st series (see Figure 1b). Maximum acceleration varied individually for animals in both series, depending on tolerance threshold, which was assessed by appearance of marked rhythm disturbances on the electrocardiogram [2]. No differences were demonstrable between the different modes of repeated exposure with respect to nature of disturbances of cardiac rhythm and pathological changes on the ECG. During exposure, a tetrapolar thoracic rheogram was recorded, from which we determined stroke volume (SV) [13], circulation volume (CV), time parameter of total peripheral resistance (TPR parameter) [7]. X-rays of the lungs were taken at the start of the long-term experiment and thereafter at monthly intervals on the 1st day after acute +Gz exposure; 4 days after the cycle of regular exposure, the animals were sacrificed by electrocution, after which the lungs were submitted to morphological examination as being the most vulnerable organ with repeated exposure to high levels of accelerations [4, 6].

Results and Discussion

Maximum tolerance of dogs assessed by appearance of marked disturbances of cardiac rhythm is illustrated in Figure 2. This figure shows that the increment of tolerance threshold constituted 3.1 G by the end of the long-term experiment (by 29%) in the 1st series and 2.7 U (20%), in the 2d. These data confirm that there is formation of long-term adaptation to +Gz accelerations with a complex profile in animals, as a result of regular exposure to them, and this is consistent with the results of previous investigations [2], where somewhat different modes of repeated exposure were used. We were impressed by the fact that, in the 1st series, the maximum adaptation effect was obtained already by the end of the 1st month and in the 2d series, only by the end of the 3d month, whereas the baseline level of mean tolerance was higher in the 2d series. On the basis of these results, it can be assumed that the greater effect of adaptation and its faster development in the 1st series are attributable to more frequent exposure.

Testing of the dogs at 8-10 G revealed the distinctions of development of adaptation of the circulatory system to repeated +Gz accelerations (Figure 3). In the baseline state, the animals of the 2d series with higher tolerance threshold presented higher CV, mainly due to tachycardia and some decrease of TPR (elevation of TPR parameter). In the 1st series, decrease of SV was

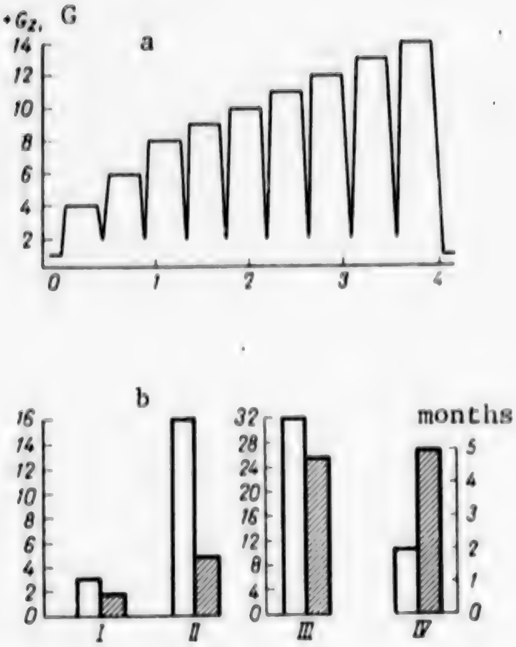

Figure 1.
Parameters of regular exposure to +Gz accelerations of increasing intensity
a) mode of exposure
b) frequency and duration of exposure
I) frequency of daily exposure
II) per month
III) total number of exposures
IV) duration of experiment (months)
White bars--1st series, striped--2d

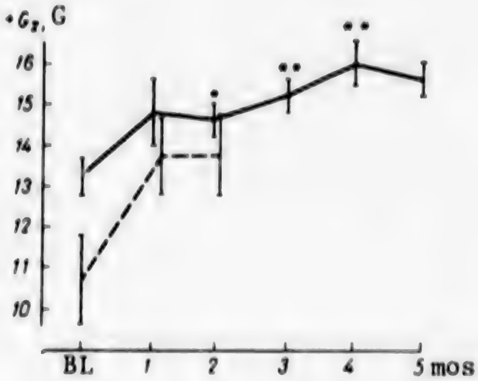

Figure 2.
Dynamics of tolerance to acceleration profiles
Here and in Figure 3:
Dashline--1st series, boldface--2d.
BL--baseline
One asterisk, $p<0.05$; two, $p<0.01$

associated with decrease of TPR were observed after 1 month, which is indicative, to some extent, of the cumulative nature of these changes. However, in the same animals, by the end of the 2d month the increase in heart rate with accelerations of 8-10 G was associated with increase in CV and recovery of SV and TPR parameter. Consequently, there was an increase in the main hemodynamic parameters aimed at maintaining arterial pressure, which was indicative of change to the vascular type of circulatory regulation. This type of regulation is considered to be adaptive, but less favorable than the cardiac or mixed type [8, 9].

Change in hemodynamic regulation of the vascular type was also observed in the dogs in the 2d series of tests, as indicated by the progressive decline of CV at the expense of SV after 3 months of regular exposure to +Gz. The hemodynamic changes were relatively more marked in the 2d series.

X-rays of the lungs revealed vascular changes such as accentuation of lung pattern and trabecularity of roots in all animals of both series (Figure 4). However, the incidence of their appearance was somewhat lower in the 2d series. Roentgenological changes on the order of lesions (sites of interstitial pneumonia, petechial hemorrhages) appeared in the dogs used in the 1st series already on the 2d-3d day of exposure. Such changes appeared in animals of the 2d series only after 2-3 months of regular exposure. The incidence of changes in the lungs was lower in the 2d series than in the 1st.

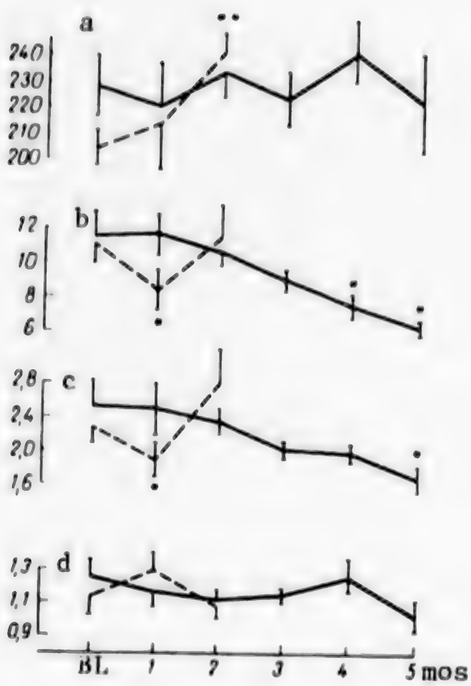

Figure 3.
Changes in hemodynamic parameters with exposure to 8-10 G accelerations
a-d) HR [heart rate] (per min), SV (mℓ), CV (ℓ/min) and TPR parameter, respectively

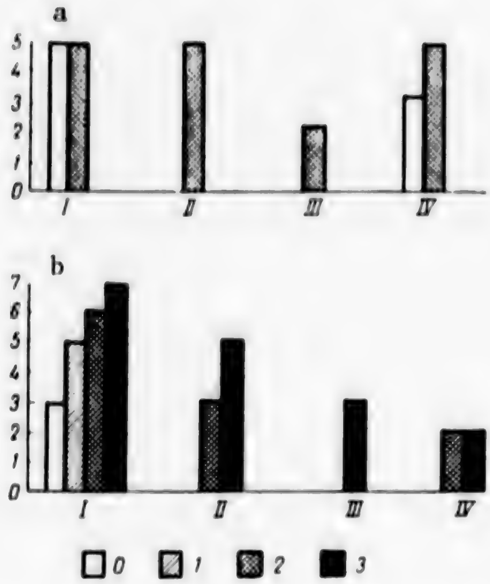

Figure 4.
Frequency of morphological changes in lungs
a) 1st series b) 2d series
0) start of experiment
1-3) after 1-3 months, respectively
X-axis: I) accentuation of lung pattern
II) trabecularity of roots
III) sites of interstitial pneumonia
IV) petechial hemorrhages
Y-axis: number of cases (animals)

The results of the morphological studies of the lungs are listed in the table. It was found that the morphological changes consisted of multiple hemorrhages, atelectases, microfocal pneumosclerosis and areas of interstitial pneumonia, which was confirmed by the roentgenological data. Marked changes were found in 5 out of 6 animals in the 1st series and only 1 out of 7 in the 2d (see Table). Thus, the results of roentgenological and morphological examination are indicative of the fact that the severity of cumulative structural and functional effects are a function of frequency of maximum tolerated +Gz accelerations in the course of regular exposure to them.

Thus, the results of comparing hemodynamic responses and bioelectrical activity of the myocardium, which were indicative of development of long-term adaptation, and results of roentgenological and morphological examination characterizing formation of primarily cumulative effects warrant the statement that there is some parallel in development of adaptive and cumulative effects resulting from regular exposure to maximum tolerated +Gz accelerations. Our findings are consistent with conceptions of the "cost of adaptation" [5] inherent in extreme environmental factors.

Incidence of morphological changes in the lungs and correlation between cumulative and adaptive effects

Series	Exposure, months	Total animals	Number of animals with morphological changes in lungs			% of each type of effect	
			marked	slight	none	cumulat.	adapt.
I	2	6	5	1	0	83±15	+29
II	5	7	1	1	5	14±14*	+10

Note: Adaptation effects--increment of acceleration tolerance threshold (%) 2 months after start of tests. Cumulative effects--incidence of morphological lesions in the lungs (% of animals with pathology). Asterisk indicates p<0.01.

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DYNAMICS OF FLUID TURNOVER IN HUMAN EXTREMITIES AS RELATED TO DIFFERENT BODY POSITIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 10 Feb 86) pp 40-45

[Article by N. Ye. Panferova and T. A. Kabesheva]

[English abstract from source] Anthropometric measurements and occlusion venous plethysmography were used to investigate fluid inflow and outflow in the limbs of human subjects who kept normal motor activity for 4 hrs, remained in recumbency or were in the head-down position at an angle of -12° and -22° (to simulate effects of zero G). During these exposures diuresis, heart rate and blood pressure according to Korotkoff were also measured. In the horizontal and, to a greater extent, head-down position, when motor activity was diminished, volume blood flow velocity in the limbs decreased, i.e., blood inflow to them became smaller. Arm volume varied insignificantly since inflow and outflow were in balance whereas leg volume decreased because fluid outflow was larger than inflow. In the head-down position the tone of leg veins also declined. Thus the peripheral vascular bed developed a complex of mechanisms that were to prevent volume overload of the central bed. Fluid shifts from the legs to the central bed were made up for by the renal excretion of water in the horizontal and head-down (-12°) position. Head-down tilt at a larger angle (-22°) produced a stressful effect on compensatory mechanisms which manifested as a greater rise of diastolic pressure and bradycardia. The data obtained indicate an active involvement of the peripheral vascular bed in the adaptation to diminished motor activity in the horizontal and head-down position of human subjects.

[Text] It is known that change from erect position (EP) of man to horizontal (HP) or antiorthostatic (HDT [head-down tilt]) position is associated with redistribution of fluid from the bottom to the top part of the body.

However, the question of dynamics of redistribution of body fluids to the region of the limbs related to change in position has not been sufficiently

investigated. The existing data indicate in essence that the volume of the lower extremities diminishes in HP and HDT.

Our objective here was to study the dynamics of redistribution of fluids to the region of the human extremities with simulation of temporary weightlessness (hypodynamia in HP and with HDT).

Methods

We conducted 4 series of tests (each lasting 4 h) on 10 essentially healthy men 25 to 40 years of age who participated alternately in each series. In the 1st series (control), the subjects maintained their usual, i.e., ambulatory , regimen of motor activity (AR), assuming the HP for 15 min at the end of each hour for the tests. Subjects participating in the 2d, 3d and 4th series remain in HP and HDT at angles of -12 and -22° for 4 h. In these series, tests were made at the end of each hour. Baseline data were obtained before each test series with the subject in HP for 15 min.

We used anthropometric methods to measure the extremities and plethysmography with Whitney mercury sensors, combined with occlusion of femoral and brachial veins. The sensors were secured over the largest perimeter of the crus and forearm. The anthropometric method was used to calculated limb volumes according to their perimeters and length. In the femoral region, measurements were taken every 3 cm from the inguinal fold to the knee, and in the crural region from the lower margin of the knee to the ankle joint; in the forearm, measurements were taken from the elbow to the wrist.

Initial decrease in crural volume when subjects changed from EP to HP and then HDT (-22°) was calculated from the plethysmogram, which was recorded continuously for 5 min.

The method of occlusive plethysmography of the vein (pressure 50 mm Hg) enabled us to determine volumetric blood flow rate in the limbs according to the rapid component of the plethysmogram, as well as rate of accumulation of extravascular fluid according to the slow component. In addition, we determined stretchability of the venous bed of the limbs according to maximum increment of their volume during additional stepped occlusion of the veins with pressure of 30 to 50 mm Hg.

With knowledge of volume rate of blood flow and volume of the limbs at the start and end of each test hour, we calculated influx (IF) and efflux (EF) of fluid in the limbs using the following formulas:

$$IF = \frac{VFR_1 + VFR_2}{2} \quad \frac{VL_1 + VL_2}{2 \cdot 100} \ m\ell/min,$$

$$EF = IF + \frac{VL_1 - VL_2}{60} \ m\ell/min$$

where VFR_1 and VFR_2 is volume blood flow rate at the start and end of each test hour (in mℓ/100 mℓ tissue/min); VL_1 and VL_2 is volume of the limb at the start and end of each test hour (in mℓ).

Concurrently, on the basis of a record of fluid intake and output, we determined overall diuresis per 4-h observation period in all series of subjects. In addition, we took an ECG in the DS lead and measured arterial pressure (BP) by the Korotkov method at the end of each hour.

Results and Discussion

The results of this study revealed that a change from EP to HP and HDT was associated with decrease in crural volume. It was the most significant in the first 5 s after active change from EP to HP, by a mean of 71% of total decline in 5 min. In the first 15 s, leg volume at the crural level decreased by 1.9±0.1 mℓ/100 mℓ tissue. If we arbitrarily assume that this is the mean change in the entire leg volume, the leg volume (its mean value constituted 16,400±132 mℓ in the subjects) diminished by 314±16.4 mℓ in 15 s. Thereafter, starting with the 1st min, leg volume changed very slowly, and in the period from the 1st to 5th min in HP this parameter decreased by another 23±6.2 mℓ.

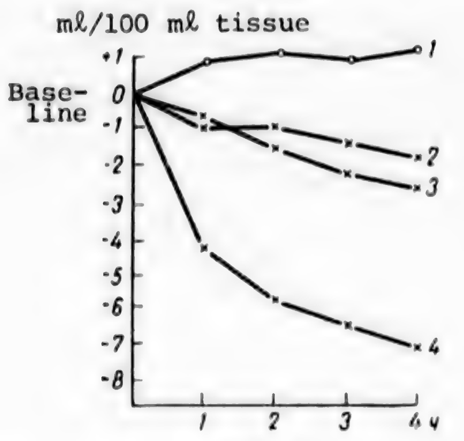

Figure 1.
Change in crural volume
Here and in Figures 2 and 3:
x-axis, time (h)
1-4) AR, HP, HTD (-12°) and HDT (-22°), respectively
×) shows reliability of differences from baseline ($P<0.05$)

Change from HP to HDT (-12 and -22°) elicited considerably less shift of fluid from the lower extremities to the central vascular bed. Mean decline of leg volume in 15 s of HDT (-12°) constituted 0.7±0.08 mℓ/100 mℓ tissue or 114±13 mℓ, and at -22° 1.1±0.08 mℓ/100 mℓ tissue or 180±11 mℓ. With HDT, the hemodynamic parameters of the upper and lower limbs changed insignificantly and unreliably ($p>0.05$)

Stabilization of leg volume did not occur during 4-h stay in HP and HDT. The decrease in leg volume progressed as a function of exposure time and angle of body tilt (Figure 1). In the course of 4 h in HP and HDT (-12°), leg volume decreased by a mean of 1.9 and 2.6 mℓ/100 mℓ tissue or by 292 and 422 mℓ, respectively. The differences in dynamics of this parameter in HP and HDT (-12°) were unreliable ($p>0.05$). With increase in tilt angle to -22°, we observed considerably greater decrease in leg volume, 3.7 and 2.7 times more than in HP and HDT of -12°. By the end of the 4th h it constituted 7.0 mℓ/100 mℓ tissue or 1262 mℓ. Changes in volume of the upper extremities under the tested conditions were unreliable ($p>0.05$) and they were unrelated to change in position.

In HP and HDT, there was a decrease in volumetric blood flow rate in the lower and upper extremities (Table 1, Figure 2). A maximum decline of this parameter was referable to the leg region in the 1st h of the test, after which the change proceeded more slowly. By the end of the 4th h in HP, HDT (-12°) and HDT (-22°), volumetric blood flow rate decreased in the leg by 29, 41 and 41%, respectively and in the arm region, by 13, 19 and 19% (see Figure 2).

Table 1. Volume blood flow rate (mℓ/100 mℓ tissue/min) in crural region of subjects during 1-h stay in AR, HP and HDT (-12 and -22°)

Conditions	Baseline (15 min HP)	Time spent in tested positions, h			
		1	2	3	4
AR	4,1±0,3	4,35±0,3	4,36±0,4	4,35±0,4	4,28±0,4
HP	4,1±0,3	3,5±0,27	3,3±0,3	3,0±0,2	2,9±0,2
HDT -12°	4,4±0,3	3,5±0,29	3,2±0,3	3,0±0,28	2,6±0,2
HDT -22°	3,9±0,2	2,9±0,18	2,7±0,25	2,5±0,25	2,3±0,2*

* $P<0{,}05$, as compared to data in HP.

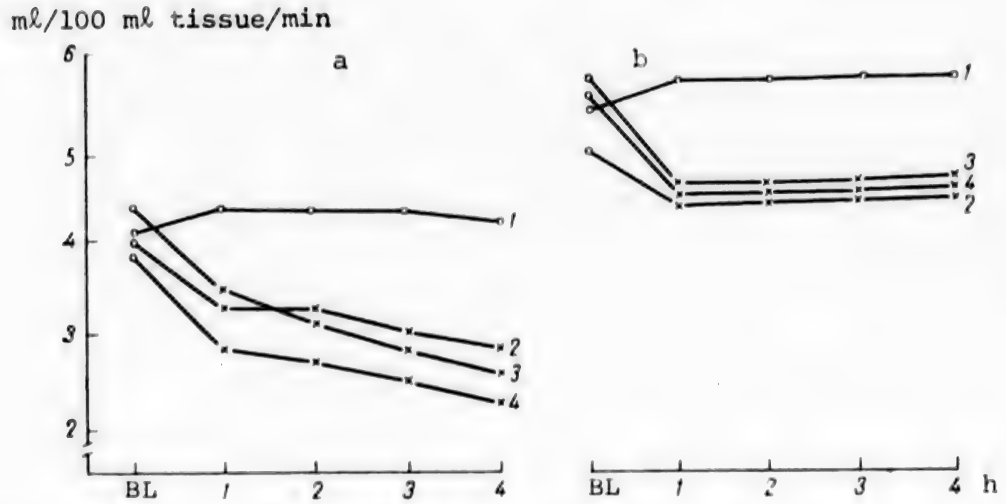

Figure 2. Volumetric blood flow rate in region of the leg (a) and arm (b); Triangle shows reliable difference between HDT (-22°) and HP parameters; BL--baseline

Slowing of volumetric blood flow rate was associated with diminished influx of blood in the indicated positions in the lower extremities, on the crural level, by a mean of 21.2, 31.8 and 32.5% (Figure 3). It should be noted that, in HDT influx of blood to the lower limbs slowed down more than in HP. However, these differences were statistically reliable only with HDT (-22°) toward the end of the 4-h observation period.

Efflux of fluid from the limbs is closely related to its influx. Analysis of the data revealed that there was dramatic decrease in fluid efflux from the lower extremities in HP and HDT (see Figure 3).

However, throughout the test period, fluid efflux from the lower limbs was always somewhat greater than influx: by a mean of 0.008 mℓ/100 mℓ tissue/min over a 4-h period of HP; by 0.015 and 0.028 mℓ/100 mℓ tissue/min with HDT (-12°)

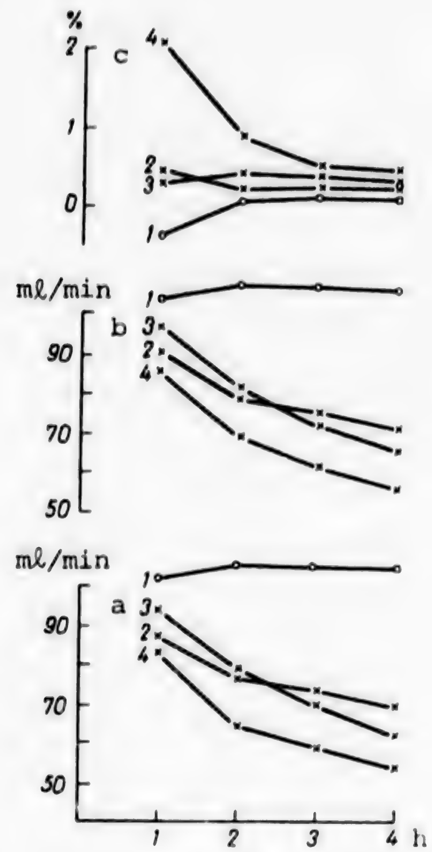

Figure 3.
Dynamics of parameters of fluid balance in region of lower limbs
Y-axes: parameters of influx (a), efflux (b) of fluid (mℓ/min) and prevalence of efflux over influx (c; %)

and HDT (-22°), respectively, which constituted for both legs 1.39, 2.46 and 4.59 mℓ/min.

Prevalence of efflux over influx was the cause of reduction in volume of the lower extremities. The prevalence of efflux over influx was the most significant in the first few seconds, after which this parameter gradually declined and was stabilized by the end of the 1st h in HP, the end of the 2d h in HDT (-12°); with HDT (-22°) no stabilization was demonstrable for the 4 h (see Figure 3).

Efflux of fluid from the upper extremities also declined concurrently with decrease in blood influx. However, these two processes balanced one another, and as a result the volume of this part of the body did not change during the tested period.

Occlusive increase in crural volume under the tested conditions was unreliable in HP, whereas in HDT position it was reliably greater than in AR and HP (Table 2). The differences between HDT (-12°) and HDT (-22°) were unreliable. Concurrently there was decline of parameter of rate of accumulation of extravascular fluid (RAEF), as determined by the slow component of occlusive plethysmograms, just like the preceding parameter: unreliably in HP and reliably as compared to HP data ($p<0.05$). With increase in tilt angle, the rate of accumulation of extravascular fluid diminished: by a mean of 0.014 and 0.02 mℓ/100 mℓ tissue/min/mm Hg in HDT (-12°) and HDT (-22°), respectively.

Table 2. Changes in parameters of occlusion plethysmography of the leg at the end of a 4-h period in AR, HP, HDT (-12°) and HDT (-22°)

Conditions	Increase in leg volume due to occlusion, mℓ/100 mℓ tissue		Rate of accumulation of extravascular fluid, mℓ/100 mℓ tissue/min/mm Hg	
	baseline	after 4 h	baseline	after 4 h
AR	1,7±0,2	+0,3±0,17	0,04±0,006	+0,004±0,002
HP	1,8±0,16	+0,3±0,17	0,03±0,006	−0,008±0,004**
HDT(-12°)	1,9±0,19	+0,8±0,11*, **	0,04±0,006	−0,14±0,001*, **
HDT(-22°)	1,8±0,16	+0,8±0,1*, **	0,04±0,006	−0,02±0,002*, **

* $P<0{,}05$ as compared to baseline data.
** $P<0{,}05$ as compared to AR data.

The increase in occlusive increment is interpreted by most researchers as an indicator of increased capacity of the venous bed or parameter of diminished venous tonus [1], and the slow component of the occlusion plethysmogram is viewed as an indicator of rate of accumulation of extravascular fluid [3, 7].

The obtained data warrant the conclusion that there was a decrease in tonus of capacitive veesels of the leg in HP and particularly HDT. Concurrently, there was a decline of RAEF directly related to angle of body inclination. Change in the latter parameter is indicative of the fact that the balance between processes of filtration and reabsorption in the microvascular system changed in the direction of prevalence of reabsorption processes in the lower limbs under the tested conditions. These parameters did not change in the forearm region under the tested conditions.

As compared to the data obtained in AR, there was increase in diuresis by 1.4, 1.7 and 1.8 times in HP, HDT (-12°) and HDT (-22°), respectively. The results of our studies revealed that diuresis increased in HP and HDT; however the differences between -12° and -22° HDT were insignificant.

Table 3. Diuresis, changes in volume of lower limbs and central hemodynamic parameters during 4 h in AR, HP, HDT (-12°) and HDT (-22°)

Conditions	Diuresis, mℓ	Leg volume change, mℓ	Pulse rate change/min	BP change, mm Hg	
				systolic	diastolic
AR	275±38	+162,0±73	+3,0±2,5	+2,8±3,0	+2,2±1,8
HP	400±32	−292,9±32*	−4,1±2,8	−3,5±2,4	+2,5±3,1
HDT (-12°)	480±36	−422,0±23*	−3,9±2,1	+1,0±3,4	+6,8±2,1*
HDT (-22°)	500±36	−1262,0±24*	−6,8±2,3*	−1,8±3,3	+8,8±2,3*

* $P<0{,}05$ as compared to baseline data (15th min in HP).

The data in Table 3 show that, with subjects in HP and HDT (-12°), fluid balance in the central bed can be provided by renal excretion of fluid: influx of fluid from the lower extremities was compensated by elimination of fluid by the kidneys. With HDT (-22°), influx of fluid from the lower limbs is greater by more than 2 times than diuresis, i.e., in this case, there is greater strain on central mechanisms of regulating circulation. Absence of changes in parameters of central hemodynamics may be due to the compensating role of diuresis in preventing a volume overload on the central vascular system under the tested conditions. The subjects showed no change in heart rate or systolic BP in HP and HDT (-12°), but there was some elevation of diastolic BP (by a mean of 6.8±2.1 mm Hg). With HDT (-22°), the elevation of diastolic BP was somewhat more marked: 8.8±2.3 mm Hg. Concurrently there was reliably slowing of heart rate by 6.8±2.3/min (see Table 3).

Thus, the results of these studies revealed that 4 h in HP and HDT (-12° and -22°) was associated with significant change in local peripheral circulation the the lower limbs and, to a lesser extent, the upper ones. Evidently, the changes in peripheral hemodynamics affect primarily the arterial bed: there is dramatic slowing of peripheral blood flow and, consequently, diminished

influx of blood to the limbs. This reaction occurred in both the lower and upper extremities, and in both HP and HDT, and it was minimally related to angle of tilt. It can be considered that it is attributable to central mechanisms of regulation and depended little on local changes in hydrostatic pressure of fluid in the extremities. The elevation of diastolic BP can be considered a consequence of generalized increase in tonus of resistive vessels. Limitation of influx of blood is important from the standpoint of adaptation, protecting the central venous bed and heart from a blood overload. Moreover, the diminished efflux of fluid from the lower limbs with HDT is also due to local mechanisms of circulatory regulation--decrease in tonus and peripheral capacitive vessels of the lower extremities.

Elimination of fluid from the body via the kidneys is a more effective, but slower mechanism of protecting the central bed against volume overloads.

The data showing absence of appreciable changes in central hemodynamics in HP and HDT are indicative of efficacy of the mechanisms of protection of the central vascular bed: there were no reliable changes in central venous pressure with HDT (-5°) [8]; with -10° HDT the pressure changes in the right atrium were mild, it did rise somewhat in the jugular vein [6]. HDT (-15 and -20°) also failed to elicit appreciable changes in pressure of the right atrium and central venous pressure; there was no appreciable change in stroke and cardiac indexes [2, 5].

Since fluid content of the lower limbs decreases in HP and HDT, the question of its redistribution in the body remains unclear. It was established that it does not pass into the peripheral bed of the upper extremities, since their volume does not change. Evidently, most of this fluid is retained in the pulmonary circulatory system. This is indicated by the pressure elevation in the left atrium and pulmonary artery [2].

Perhaps, fluid may be partially redistributed in the jugular vein system. Since the capacity of vessels is dramatically limited, one could expect that there is increased delivery of blood to the bed of the external jugular vein. This is indicated by the plethora of head tissues in HP and particularly HDT.

In turn, elevation of pressure in the left atrium, pulmonary artery system and head vessels could serve as a triggering mechanism for intensification of fluid-excreting function of the kidneys [4].

However, as shown by the results of this study, regulation of fluid metabolism by means of eliminating fluid from the body through the kidneys in HDT with a large tilt angle (-22°) is limited. This is associated with more marked changes in central hemodynamic parameters, i.e., with HDT (-22°) the efflux of blood from the limbs is not compensated by renal elimination of moisutre, and there is a greater load on the central vascular bed.

On the basis of the studies it can be concluded that, in HP and HDT, there are efficient mechanisms of regulating metabolism of fluids, which prevent overfilling of the central circulatory bed.

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FUNCTIONAL STATE OF THE HUMAN CARDIORESPIRATORY SYSTEM FOLLOWING 30-DAY ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 13 Jun 86) pp 46-48

[Article by G. V. Machinskiy, V. P. Buzulina, V. M. Mikhaylov and E. I. Nechayeva]

[English abstract from source] Before and after 30-day head-down tilt (-8°) the cardiorespiratory function of six healthy volunteers was assessed using an exercise test (aerobic workload on the treadmill that grew to the maximal level). After hypokinesia the maximal oxygen consumption decreased by 9.9% and total oxygen debt by 23% ($P<0.05$). The bioelectric activity of the heart showed a decrease of the T_A wave by 34% and the T_D wave by 30% ($P<0.05$). These changes give evidence that the functional capacity of the cardiorespiratory system declined and as a consequence the ability of the test subjects to perform sustained physical work of aerobic character also decreased.

[Text] Investigation of the effect of restricted motor activity on human tolerance to stress factors is still one of the pressing problems of aerospace and naval medicine [2, 9, 13].

Our main objective here was to assess the functional capacities of the cardiorespiratory system of healthy man during performance of physical exercise of maximum intensity after being submitted to antiorthostatic [head-down tilt] hypokinesia (HDT).

Methods

Six essentially healthy men 31.5±1.9 years of age participated in the studies; they were submitted to HDT (-8°) for 30 days. During this period, their activity was restricted to bedrest.

As a functional load test we used walking on a treadmill at the rate of 7 km/h with changing angle of inclination of the unit. They walked until total fatigue appeared, i.e., as long as they could move at the specified speed. The test was preceded by a 6-min warm-up in the form of slower walking. The figure illustrates the protocol of the test.

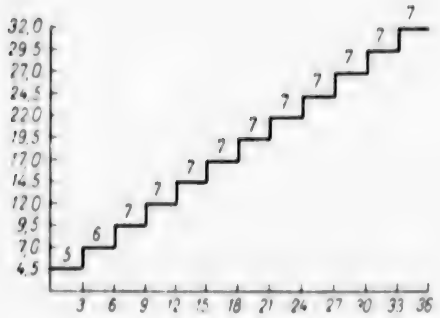

Diagram of functional test involving wal on treadmill
X-axis, duration of exercise (min), y-axis, angle of treadmill slant (%); numerals above the "steps" indicate velocity of movement (km/h)

Parameters of the cardiorespiratory system, electrocardiogram (ECG) and arterial pressure (BP) were recorded during the treadmill test.

We analyzed the following parameters: how long they walked on the treadmill (min), distance traveled (m), critical force of obtained load (kg-m/min), heart rate (HR/min), minute volume (MV, ℓ/min), maximum oxygen uptake (MOU, mℓ/min/kg), respiration rate (RR/min), oxygen pulse (OP, mℓ/beat), coefficient of oxygen utilization (CO_2U, mℓ/ℓ), ECG in the three Nehb leads, systolic BP (BP_s, mm Hg), diastolic BP (BP_d, mm Hg), pulsed BP (BP_p, mm Hg) and total oxygen debt(TOD, ℓ). Calculation of TOD and its fractions was made by a method proposed previously [14] as modified in [1].

The results of these studies were processed using Student's T criterion.

Results and Discussion

The subjects tolerated rather well maximum exercise on the treadmill during testing in the baseline period. The principal cause of stopping the test was fatigue of muscles of the thigh and lower leg, which is typical of individuals of a young and middle age with high functional capacities of the cardiorespiratory system [8, 10]. Repeated testing in the baseline period showed good reproducibility of the findings. The changes in bioelectrical activity of the heart and blood pressure were consistent with the workload.

After HDT, the subjects tolerated the treadmill test much worse. They stopped walking mainly due to the subjective sensation of dyspnea, often associated with marked general weakness and vertigo.

Onset of these symptoms during heavy exercise is typical of subjects who were deconditioned by prior hypokinesia and those in the older age group, with poorer regulation of the cardiorespiratory system than young subjects [4-6].

It is known that dyspnea is usually attributable to a combination of changes--increased metabolic demand, intensification of ventilation reaction, increased resistance to respiration and diminished strength of respiratory muscles [15]. It should be noted that, in thus study, the subjective sensation of dyspnea and shortage of air were not associated with increase in RR, while MV even decreased at the end of the treadmill test following HDT, as compared to the baseline (see Table). Evidently, it is necessary to conduct special studies to investigate the etiology and pathogenesis of dyspnea following HDT.

Performance of the treadmill test on the 1st day of the recovery period was associated with an HR that was virtually the same as in the baseline period on the average for the group. MOU and OP decreased reliably, while

Some of the physiological parameters recorded during maximum exercise on treadmill before and after 30-day HDT (M±m)

Parameter	Before HDT	After HDT	Change, %
HR/min	193,2 ± 4,2	191,2 ± 4,4	− 1,1
MV, ℓ/min	110,2 ± 7,8	97,3 ± 5,3	− 11,7*
MOU, mℓ/min/kg	39,2 ± 1,3	36,3 ± 0,9	− 7,3*
OP, mℓ/beat	18,1 ± 0,4	16,4 ± 0,3	− 9,4*
CO_2U, mℓ/ℓ	32,2 ± 1,5	32,5 ± 1,3	· 0,9
TOD, ℓ	9,1 ± 0,9	7,5 ± 0,4	− 17,6*
T_D, mm	4,3 ± 0,5	3,0 ± 0,6	− 30,3*
T_A, mm	7,5 ± 0,7	5,0 ± 0,7	− 34,4*
P_A, mm	15,8 ± 1,2	17,0 ± 2,0	+ 7,6
BP_s, mm Hg	180,3 ± 5,3	177,5 ± 5,6	− 1,6
BP_d, mm Hg	79,8 ± 6,6	77,8 ± 6,3	· 2,6
BP_p, mm Hg	100,5 ± 10,4	99,6 ± 6,2	· 0,9

* $p < 0,05$.

bioelectrical activity of the heart was characterized by 34% decrease in amplitude of T_A wave and 30% decrease in T_D wave. The BP changes were insignificant (see Table).

Long-term HDT, which had an adverse effect on aerobic capacities of the subjects, lowered their general physical endurance. In particular, test time decreased on the average from 19.2 to 15.7 min, i.e., by 19% ($p<0.01$). The distance traveled diminished from 2105 to 1682 m, or by 21% ($p<0.01$), while critical power decreased from 2570 to 2197 m, i.e., by 14% ($p<0.01$).

Decline of physical work capacity and aerobic strength after 30-day HDT was associated with an appreciable decline of TOD, mainly due to decrease of the "slow component from 5.61 to 4.29 ℓ, or by 23% ($p<0.05$). The direction and extent of TOD change were comparable to the results of tests involving 49-day HDT, where maximum exercise was performed on a cycle ergometer [3], and apparently this was indicative of diminished efficiency of bioenergetic implementation of body functions.

The electrocardiographic changes were characterized mainly by moderate increase in amplitude of P_A and T_A, and decrease in amplitude of T_D, which is indicative of worsening of myocardial bioenergetics [7]. The BP reaction to maximum workload did not change appreciably.

Thus, the results of these studies enabled us to determine that 30-day restriction of motor activity in antiorthostatic position had an adverse effect on functional capacities of the cardiorespiratory system during intense muscular exercise, as a result of which there was a decrease in capacity to perform aerobic exercises for a long period of time. Aerobic work capacity following HDT became limited by the cardiorespiratory, rather than muscular, component.

A comparison of the data obtained in this and other studies revealed some differences in extent of decline of aerobic capacity of the subjects. Thus, while MOU decreased by 9.9% in our study, in a previous study with HDT of analogous duration the decline of this parameter during exercise on a cycle ergometer constituted 16.6% [5]. In this regard, the assumption was expounded that the noted difference could be attributable to the type of test exercise. However, analysis of the literature failed to confirm this assumption. Thus, a 26.4% decrease in MOU was observed during exercise on a cycle ergometer after 20-day bedrest [16], and a 28% decrease in the same subjects in the case of treadmill exercise [11]. A study of 5 subjects who exercised daily for 15 min revealed, after 30-day bedrest [12], an 8% decline of MOU when exercising on the ergometer and 10% decrease when walking on a treadmill.

Consequently, there are grounds to assume that the differences in decline of functional capacities of the cardiorespiratory system, in both these tests with HDT and those conducted previously, are attributed mainly to the extent of restriction of motor activity of subjects during bedrest, rather than the form of test load.

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VARIANT OF QUANTITATIVE EVALUATION OF MECHANISMS OF CENTRAL HEMODYNAMIC ORTHOSTATIC REACTIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 7 Jan 86) pp 48-52

[Article by P. A. Titunin, M.L. Sveshchinskiy, V. F. Chudimov and S. F. Zerov]

[English abstract from source] This paper describes an approach that can help clarify mechanisms of central circulation of orthostatic men using a mathematical model and noninvasive methods of examinations. Circulation parameters such as peripheral resistance (PR), arterial compliance (Ca), and ratio of vein compliance (Cv) to the pump coefficient of the heart (β) were determined by the "partial identification" method of the two-component circulation model with the aid of cardiac output and arterial blood pressure measured by tetrapolar thoracic rheography and tachooscillography. The paper also contains physiological interpretation of the above parameters as related to the upright posture of man. Peripheral resistance in the head-up position characterizes both the degree of arterial vasoconstriction and the state of the so-called muscle pump. Blood displacement to the lower body results in an increase of the ratio $Cv \cdot \beta$. The orthostatic reaction of circulation of 28 healthy male subjects was investigated. Blood pooling in the lower body, with venous and cardiac reactions being manifest, led to the fall of arterial pressure and cardiac output to 67% when compared with the pretest level. The change in the properties of resistance vessels (Ca and PR) accelerated the recovery of the arterial pressure value.

[Text] Orthostatic factors have gained wide use in clinical practice as a test and for investigation of functional capacities of circulatory regulatory mechanisms [6, 12, 17, 19]. Orthostatic tests acquire special relevance in the area of testing the adaptive capacities for weightlessness [14, 21]. The existing methods of testing man do not permit making a quantitative evaluation of the contribution of different mechanisms of the circulatory postural reaction [10, 18]. Use of mathematical modeling methods is one of the directions toward solving this problem [5, 16]. Analysis of orthostatic circulatory changes with use of mathematical models has been the subject of only very few works [2, 3, 10].

We shall discuss here the capabilities of a method of quantitative evaluation of mechanisms of central hemodynamics of man under orthostatic conditions with use of a mathematical model and noninvasive test methods.

Methods

We measured the following central hemodynamic parameters: stroke and circulation volume by tetrapolar thoracic rheography after Kubicek followed by calculation of stroke (SI) and cardiac (CI) indexes, systolic (BP_s), diastolic (BP_d) and mean arterial blood pressure (BP_m) by the tachooscillographic method. Evaluation and quantitative analysis of the contribution of properties to hemodynamic status were made using the two-component model of V. A. Lishchuk et al. [15] and previously proposed method of "partial identification" of parameters [13]. We studied the orthostatic circulatory responses of 28 healthy males 18-26 years of age.

Results and Discussion

In selecting a mathematical model, a compromise was made between full description of the circulatory system and feasibility of identifying parameters (calculation of properties of circulation) in favor of a simpler two-component model, but one that is identifiable under clinical testing conditions. The model enables us to examine mechanisms of implementing the main central hemodynamic functions: maintaining BP_m and blood flow by means of such properties as peripheral vascular resistance (PR), elasticity of arteries (Ca), elasticity of veins (Cv) and cardiac pump coefficient ($1/\beta$).

The method of partial identification of parameters of the two-component model was elaborated for use with the human body in horizontal position. However, since the model does not consider the gravity vector, there are some distinctions to physiological interpretation of the properties assessed.

Within the limits of the identification used, unlike the Poiseuille formula, PR is determined in the following manner:

$$PR = BP_m/CI$$

Venous pressure is disregarded since it is considerably lower than BP_m.

The results of the studies conducted by R. D. Grigoryan et al. [9, 10], revealed that, in erect position, neither the height of the blood column (angle of body inclination) nor change in any parameter (with the exception of actual peripheral resistance of various vascular segments) has an appreciable influence on calculated PR. However, the "muscle pump" mechanism, which is largely involved in movement of blood in the leg artery-vein segment, affects the identified PR. The greater the involvement of the muscle pump, the lower the value of PR.

Without touching upon comprehensive studies using many-component models, we can make the following comments about these facts. The selective change in some parameter (for example, decrease in elasticity of one of the vascular reservoirs) leads to local pressure elevation followed by redistribution of

blood volumes over the entire cardiovascular system. Influx of additional volumes of blood leads to pressure elevation in each vascular segment with change in volumetric blood flow. This is associated with increase in BP, influx of blood to the heart, venous pressure and, consequently, cardiac output.

Proceeding from Poiseuille's equation, we should expect that the extent of increment of circulation volume and BP_m could be similar and, consequently, change in compliance would not affect the identified PR.

Analogously, we can become convinced that there is no effect on the part of changes in pumping function of the heart on nominal PR. If only the hydrostatic component of the column of blood is selectively included in the mathematical model, we shall see that, under orthostatic conditions, volumetric blood flow in arterial vessels to the lower half of the body will increase under the influence of blood pressure in arterial vessels on the level of the heart, and the weight of the column of blood, the pressure of which in the aorta-leg arteries segment could reach 100 mm Hg. On the other hand, in the leg vessels-central veins segment, there is a gravity component of the same magnitude that prevents efflux of blood. As shown by model studies, after a certain time of exposure to the gravity factor, the circulatory system changes to a new equilibrated state characterized by presence of blood deposited in the lower half of the body and reciprocal cancelling out of gravity components in arterial and venous vessels, as manifested by persistently low volumetric blood flow. If there is no change in peripheral resistance of different vascular regions, the extent of BP decline will be proportionate to the extent of decline of cardiac output. Consequently, the gravity factor does not affect the calculated PR. The muscule pump mechanism can be described in different ways in mathematical models. But its ultimate contribution will be to increase the flow of blood between two vascular regions, often counter to the pressure gradient. This mechanism can also be viewed as a decrease in PR between vascular segments. On the other hand, the peripheral resistance of these vascular segments is a component of PR.

Thus, in erect position PR is characterized not only by the extent of vasoconstriction of arteries and viscosity of blood, but the contribution of the muscle pump.

Elasticity of the arterial reservoir (Ca) was calculated using Frank's equation:

$$Ca = \Delta V/\Delta P = SI/(BP_s - BP_d) \qquad (1)$$

where ΔV and ΔP is increment of volume and pressure in an elastic reservoir. No distinctions were found to physiological interpretation of Ca in analyzing orthostatic responses.

The role of elasticity of the venous reservoir (Cv) and pumping function of the heart ($1/\beta$) were studied with calculation of the ratio between them:

$$Cv:1/\beta = (V_t - BP_m \cdot Ca)/CI \qquad (2)$$

where V_t is tension blood volume, the value of which is determined by volume of circulating blood and vascular tonus.

The statistically mean value for tension blood volume of 765 mℓ/m^2 was identified by invasive monitoring in cardiovascular surgical practice. According to equation (2), the arbitrariness of evaluating V_t in each specific instance is compensated by the corresponding shift in value of $Cv \cdot \beta$. Thus, if the individual value exceeds 765 mℓ/m^2, as a result of identification a low value will be obtained for $Cv \cdot \beta$. This can be interpreted as decrease in elasticity of veins, and the physiological significance of this reaction is similar to an increase in blood volume. Thus, with the human body in horizontal position, the integral parameter $Cv \cdot \beta$ characterizes elasticity of veins, pumping coefficient of the heart and filling of the vascular system.

Identification of Cv under static conditions, with availability of data about central venous pressure, amounts to the following equation:

$$Cv = (V_t - P_a \cdot C_a)/P_v \tag{3}$$

where P_v and P_a are venous and arterial pressure. A certain assumption is made here: central venous pressure is taken as a certain concentrated mean for the venous system. With man in erect position, due to deposition of blood in the lower half of the body, there is a decline of central venous pressure. As a result C_v rises. The extent of blood deposition and, consequently, extent of decline of central venous pressure will be determined primarily by the elastic properties of the venous system and all components of the muscle pump mechanism. Thus, in erect position, parameter Cv characterizes both the state of the vascular wall of the venous system and extent of deposition of blood.

Using the expression $\beta = P_v/CI$, we convert equation (1):

$$C_v:1/\beta = (V_t - P_a \cdot C_a)/CI \tag{4}$$

with appropriate interpretation of the physiological relevance of this parameter with man in horizontal and erect positions.

The quantitative contribution of parameters to formation of mean arterial blood pressure and circulation volume can be found by inserting the values of parameters in the model:

$$BP_m = V_t/(C_v \cdot \beta/PR + C_a),$$

$$SI = V_t/(C_v \cdot \beta + C_a \cdot PR)$$

In a study of the circulatory system of healthy men in horizontal position (in 5th min) and standing erect (5th min), identification was made of the parameters and analysis was performed of their contribution to hemodynamic status. The circulatory parameters and dynamics of changes in them in orthostatic position were consistent with data in the literature [1, 4, 11, 17]. Cardiac output decreased by 33% with change from horizontal to erect position, and there was a tendency toward elevation of BP_m. PR and $Cv\beta$ rose reliably in response to active orthostasis, and there was decrease in elasticity of arteries.

The circulatory changes in response to orthostatic factors can be put in the following order: deposition of blood in the lower half of the body with compensatory change in elastic properties of the venous reservoir and in

pumping function of the heart (parameter $C_v \cdot \beta$), compensatory increase in PR and change in strength of arterial vessels. The central hemodynamic changes were studied on a model with successive substitution of values for parameters corresponding to horizontal position to levels corresponding to vertical position. Under the effect of the hydrostatic column there is deposition of blood in vessels of the lower half of the body which, in the presence of venous and cardiac reactions, leads to decline of BP and cardiac output to 67% of the baseline. The change in properties of resistive vessels (C_a and PR) is instrumental in restoring BP.

The method of assessing circulation with a two-component model can be used for quantitative analysis of central hemodynamic orthostatic reactions. It should be borne in mind that PR with man in erect position characterizes both the extent of arterial vasoconstriction and state of the muscle pump, and the value of parameter $C_v \cdot \beta$ under orthostatic conditions reflects the reaction of veins and the heart combined with postural redistribution of blood volumes. Orthostatic drop of BP_m and cardiac output is related primarily to increase in $C_v \cdot \beta$. In healthy people, orthostatic increase in PR is instrumental in restoring BP.

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STATUS OF α_1-ADRENERGIC REGULATION OF STROKE VOLUME IN HYPOKINETIC RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 31 Jan 86) pp 52-55

[Article by A. S. Chinkin]

[English abstract from source] The positive effect of phenylephrine (PE) on stroke volume (SV) was 3 to 5 times weaker in the rats exposed to hypokinesia for 30 days as compared to the controls. After obsidan blockade of α_1-adrenoreceptors SV increased in both groups and the intergroup differences in the PE effect remained significant but less pronounced. This can be attributed to a greater effectiveness of PE after obsidan administration during hypokinesia. Correlation analysis showed that the weak effects of PE on SV were potentiated by obsidan (potentiation was the stronger the weaker the effects) while the distinct effects were on the contrary inhibited. This demonstrates the synergy-antagonism relationships in the PE and obsidan interaction and seems to indicate that the common site of their action is α_1-adrenoreceptors. After phentolamine injections the PE effect on SV was not found. In this situation SV decreased; the SV decrease as well as its increase under the action of obsidan was less significant in the hypokinetic than in the control rats. The above investigation suggests that the activity of α_1-adrenoreceptors involved in the actualization of positive effects of agonists on SV is considerably lower during hypokinesia.

[Text] Postsynaptic α_1-adrenoreceptors (aAR) were discovered in the mammalian heart almost 20 years ago [15]. Since that time a considerable number of articles has been published (particularly in the foreign press) that contain information about their role in regulating cardiac functions [6, 9, 11]. It was shown that they are involved primarily in implementing the positive inotropic effect of α_1-adrenoagonists (for example, epinephrine and phenylephrine) on the myocardium [12, 14]. However, in essence the activity of these receptors as related to different conditions of mobility has not been investigated, including their behavior during hypokinesia, which has become a pressing problem of biology and medicine in the last decades. In view of the absence of direct data, the role of aAR in regulation is not clear enough with respect

to such an important parameter of circulation and pumping function of the heart in the intact organism as stroke volume of blood (SV), which is closely related to contractile function of the myocardium. We undertook this study in order to explore these questions.

Methods

White male rats weighing 300-350 g were divided into 2 groups. The 1st group (15 animals) served as the control and was kept in ordinary cages (7-8 in each) at a temperature of 15-20°C. The rats in the 2d group (10 animals) were put in individual box-cages for 22-23 h/day for 30 days, which limited their motor activity, and they were transferred to one large cage for 1-2 h daily. Duration of stay in the confined cages was increased gradually over a period of 15 days prior to the basic experiment. These measures served to attenuate the stress reaction inherent in hypokinesia [2, 4]. After the period of hypokinesia, both groups of animals were anesthetized with urethan (1.25 g/kg) and given atropine to preclude baroreflex bradycardia via the vagus nerves (1.5 mg/kg subcutaneously). Tetrapolar transthoracic impedance rheography and an RPG-204 instrument were used to determine SV. This instrument enables us to measure impedance the range of 10 to 3000 Ω at a frequency of 100 kHz with baseline resistance of 2×100 kΩ. Needle electrodes were implanted subcutaneously to record differential rheograms: exploring ones on the level of attachment of the clavicle to the sternum and xiphoid process and active ones, on the lower lip and right thigh. Rheograms were recorded with use of an N-338 ink recorder at the following times: before and 10 min after giving atropine, before and after successive (at 10-12 min intervals) injections of increasing doses of phenylephrine (1.66, 5 and 10 μg/kg) 8-10 min after obsidan (propanolol hydrochloride, 0.1%, 5 mg/kg subcutaneously) and repeated injection of the same doses of PE after obsidan. Then, to block aAR, phentolamine (5 mg/kg) was injected intravenously and 5 min later, another PE injection in a dosage of 5 μg/kg was given. Tape feeding rate in recording rheograms was 100 mm/s.

PE concentration in isotonic NaCl solution constituted 0.5 mℓ/kg. Phentolamine content in solution was 5 mg/kg.

SV was calculated using the formula of Kubicek [10], considering specific blood resistance to be 150 Ω/cm. Efficacy of PE was assessed according to maximum difference between SV just prior to injection and 40 s after it.

Results and Discussion

The results of our study revealed (see Table) that at relative physiological rest SV was somewhat lower in the 2d group than in the 1st. With use of atropine, a tendency toward decline of this parameter was noted in both groups of animals.

Marked intergroup differences were demonstrable in responses of the tested parameter to PE. The positive effect of all tested doses of this agent was considerably greater in animals of the 1st group than the 2d ($p<0.01$-0.02). There was a particularly large difference (5-fold) in reactions to the lowest dose, 1.66 μg/kg. It was subliminal in a number of animals of the 2d group, which is indicative of a decline in their sensitivity to PE, as compared to

control animals. A maximum response was obtained with a dosage of 5 μg/kg. Two-fold increase in dosage was associated with increased reaction in only some of the rats in both groups. In the others, there was attenuation of the effect, and the dose-effect curve became bell-shaped, which is apparently a manifestation of autoantagonism in the mechanisms of action of PE. The fact that depression occurred in the 2d group at a considerably lower level of effects than in the 1st group is apparently indicative of corresponding change in maximum SV increment under the effect of PE under hypokinetic conditions.

Changes in SV in hypokinetic and control rats under the effect of phenylephrine before and after successive blocking of β- and α_1-adrenoreceptors

Group	Adreno-blocking agent	Baseline mℓ	After giving phenylephrine, μg/kg			After giving obsidan or phentolamine (5.0 mg/kg)
			1.66	5.0	10.0	
1	—	0,26±0,02	0,093±0,015	0,115±0,018	0,119±0,029	0,116±0,026*
2	—	0,22±0,01	0,018±0,016	0,036±0,016	0,032±0,06	0,046±0,018*
P		>0,05	<0,01	<0,01	<0,02	<0,05
1	Obsidan	0,39±0,03*	0,097±0,023	0,126±0,021	0,148±0,027	—0,116±0,022*
2	»	0,28±0,03*	0,028±0,004	0,061±0,015*	0,065±0,031	—0,047±0,027
P		<0,05	<0,01	>0,05	<0,05	>0,05
1	Obsidan + phentolamine	0,28±0,05*	—	0,003±0,006*	—	—
2	Same	0,24±0,03	—	0,004±0,004*	—	—
P		>0,5		>0,5		

*Reliable ($p<0.05$) change in effect of agents on animals in indicated groups due to adrenoblocking.

On the basis of these data and considering interaction of PE mainly with aAR, and only in high concentrations with β-AR [11, 12], it can be considered that activity of aAR determining the beneficial effect of agonists on SV is diminished under hypokinetic conditions. At the same time, the possibility could not be ruled out that the tested doses of PE were rather high for control animals and partially activated β-AR. For this reason, xperiments were continued after giving obsidan, a β-blocking agent.

However, the results of these experiments were unexpected in many respects. In the first place, there was reliable increase in SV in response to obsidan in both groups of animals, which is in contradiction to the existing conception of negative inotropic effect of β-adrenoblocking on cardiac function. The positive effect of obsidan reached more than 90% of the baseline in some tests in control animals. During hypokinesia, the effect was lower by a mean of 2.5 times than in the control ($p<0.05$). In the second place, after blocking β-AR with obsidan, the effect of the same doses of PE not only failed to diminish or remain at the former level, but in many cases it increased: by 1.5-2.5 times in the 2d group with doses of 1.66-5 μg/kg; $p<0.05$-0.02, in the 1st group, we observed merely a tendency toward increase of this parameter. True, the effect on the latter, even under these experimental conditions, was reliably higher than in hypokinetic animals (with the exception of a dosage

of 5 μg/kg); however, the differences became less significant. For this reason, the results obtained with use of obsidan apparently require special discussion. According to information in the literature [13], propranolol has a positive inotropic effect via aAR on the myocardium, and this should in turn lead to increase in SV. This is also indicated by the results of the present study. First of all, as shown above, less increment of SV was observed under the effect of obsidan in hypokinetic animals characterized by mild activation of aAR by PE. Moreover, the interaction between obsidan and PE apparently demonstrates synergism-antagonism or competitive dualism, which is indicative of their action via the same active center of a receptive structure [3], and serves as an indication of involvement of aAR in expression of the positive effect of obsidan on SV. Indeed, as shown by analysis, the correlation between PE effect on intact adrenoreceptors and change in effect in the presence of obsidan has a rather high coefficient with a negative sign--for both groups of animals together it is 0.633. (Considering the possible autoantagonism in effect of PE, we took the maximum effects of PE for analysis for each animal, regardless of dosage, but in most cases with 5 μg/kg). Analysis of the data for each group separately revealed that the coefficient increased, constituting 0.697 for the 1st group of animals and 0.827 for the 2d. Hence, the relatively mild effect of PE in both groups was potentiated by obsidan in terms of synergism, whereas rather marked effects, on the contrary, were depressed, and this is indicative of synergism-antagonism in the interaction of these agents.

These data also indicate that the decrease in intergroup differences with use of PE after obsidan is most probably attributable to the above-mentioned correlation between obsidan and PE via aAR and low response to PE when adrenoreceptors are intact, rather than the fact that PE had an appreciably activating effect on β=AR in control animals with intact adrenoreceptors or the fact that in hypokinetic animals aAR have the capacity for greater activation in the absence of β-adrenergic influences. In other words, if the effect of obsidan amounted merely to blocking β-AR, the intergroup differences in effect of PE following obsidan would be more significant.

Upon subsequent administration of phentolamine, i.e., with combined blocking of aAR and β-AR, as was to be expected, PE no longer had a significant effect of SV in either group. In some cases, the effect remained positive but considerably attenuated, whereas in others there was either no effect or it was negative. However, exclusion of aAR per se does have some effect on SV. There is decline of stroke volume which, however, is statistically reliable ($p<0.001$) only in control animals. In the 2d group, the effect was considerably less marked in most experiments, and it was even absent in two of them. This indicates that, under hypokinetic conditions, the role of aAR in expression of the effects of endogenous catecholamines (epinephrine and dopamine [11, 12]) on SV is considerably diminished, in spite of the fact that their levels in blood and urine are higher than in the control [1]. At the same time, it can be assumed that expressly the surplus of these amines is the cause of desensitization of aAR under hypokinetic conditions. However, this question requires special investigation.

Thus, the results of this study revealed that aAR are involved in regulating SV, and their activity diminishes under hypokinetic conditions.

However, we cannot determine from the findings of this study the extent to which PE has a specific positive inotropic effect on SV. It is known that catecholamines and PE, which act through vascular aAR, can also influence SV [5]. However, the results of other studies enable us to differentiate, to some extent, between the effects expressed via myocardial aAR. It has been shown that the latter have an important distinction: unlike vascular aAR, they are virtually not activated by norepinephrine [12]. It is also important to note that, after giving obsidan, in spite of the fact that aAR are intact, no positive effect of norepinephrine on SV is demonstrable [6]. Moreover, in most experiments, the effect of norepinephrine becomes negative, whereas the effect on SV of epinephrine which is capable, like PE, of activating aAR not only of smooth muscle cells of vessels but the myocardium [12], is enhanced by obsidan [6]. Hence, activation of vascular aAR without the positive inotropic effect of adrenoagonists is apparently insufficient to increase SV. This, in turn, warrants the belief that the "systolic" effects of PE and their attenuation under the influence of hypokinesia are largely related to myocardial aAR. This conclusion is consistent with data to the effect that, under hypokinetic conditions, the effect of epinephrine on parameters of myocardial contractile function is also attenuated [7].

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ADAPTABILITY OF THE RAT HYPOKINETIC HEART TO AFTERLOAD, AND THE ROLE OF NERVOUS REGULATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, Mar-Apr 87 (manuscript received 6 Jan 86) pp 55-58

[Article by V. I. Kuznetsov and G. M. Pruss]

[English abstract from source] Adaptation of the heart of hypokinetic rats to sustained afterload and the role of nervous regulation in this process were investigated. The experimental rats were subdivided into four groups: 1) control, 2) hypokinesia for 64 days, 3) coarctation of the aorta for 4 days, and 4) hypokinesia for 60 days plus coarctation of aorta for 4 days. It was found that the rates of contraction and relaxation of the heart increased by 22 = 51% in the Group 2 rats and decreased by 32 = 40% in the Group 3 rats as compared to the controls. Coarctation of aorta that followed 60-day hypokinesia (Group 4) reduced the increased parameters to the control level. After heart denervation (vagotomy and drug desympathization) all the rats showed depression of the contractile parameters to a varying degree: Group 2 rats exhibited the lowest degree of depression. It can be concluded that cardiac resistance of the hypokinetic rats to afterload is higher than in the intact rats with coarctation of aorta; on the other hand, afterload reduces the hypokinesia-induced increase in the contractility function, making it close to the control level. In addition to the nervous influences (sympathetic), intracardiac factors play an important role in the mechanisms of adaptation of the heart to hypokinesia and of the hypokinetic heart to afterload.

[Text] It has been established that the "hypokinetic" rat heart has increased resistance to stress-induced lesions [7]. Studies on humans whose movements were restricted revealed the qualitative and quantitative change in effects of emotional stress on cardiac function, which is related to change in regulation of the cardiovascular system [8]. The question of adaptability of the hypokinetic heart to afterload occurring acutely and the role of the neurological factor in this process is of interest.

Methods

Experiments were performed on 25 mongrel female rats weighing 182-286 g. The animals were divided into four groups: the 1st consisted of control animals, the 2d of rats submitted to 64 days of hypokinesia (HK), the 3d consisted of intact rats with coarctation of the aorta for 4 days, the 4th of animals submitted to HK for 60 days and then coarctation followed by 4 days of hypokinesia. HK was produced by keeping the animals in groups in special tight cages separated into 3 compartments, with 3-4 animals in each. Additional afterload on the heart was produced by constricting the aorta in the subdiaphragmatic region [4]. Contractile function was evaluated according to strength parameters--rate of contraction in acute experiments under urethan anesthesia (160 mg/100 g). Pressure in the left ventricle (Pv) was recorded with the chest open and under artificial respiration using a cannula introduced into the left ventricle through the apex and connected to a sensor from a Mingograph-81 electromanometer. We calculated maximimum myocardial contraction and relaxation rates (MCR and MRR, respectively), as well as IFS index, which is the product of multiplying developed pressure by heart rate (HR) as related to unit of left ventricular mass [5]. To determine maximum myocardial capacity, we conducted a test with 30-s ligation of the ascending aorta, and pressure was recorded in the 5th s of ligation. The tests were conducted with intact nervous regulation and again 5 min after vagotomy and pharmacological blocking of α- and β-adrenoreceptors (with dihydroergotoxine in a dosage of 0.05 mg/kg for the former and obsidan in a dosage of 0.5 mg/kg for the latter, which were injected successively into the right ventricle.

The results were submitted to statistical processing with use of Student's criterion. The heart of 2 rats submitted to 64-day hypokinesia stopped after denervation. The data on these animals were not included in the results of this investigation.

Results and Discussion

As can be seen in the table, there was 28 and 51% increase in MCR and MRR respectively, as compared to the control in a state of relative physiological rest with intact nervous regulation in animals submitted to 64-day hypokinesia. HR slowing, decrease in MCR and IFS by 28, 32 and 40%, rexpetively, was observed in intact rats with coarctation. In animals submitted to 60-day HK, coarctation of the aorta elicited return to control levels of MCR and MRR, which had been elevated during hypokinesia.

If we compare the rats in the 3d and 4th groups, we shall find that, at relative physiological rest, Pv, MCR and IFS were higher by 30% ($p<0.05$), 61% ($p<0.02$) and 40% ($p<0.01$), respectively, in the 4th group, as compared to analogous parameters for animals in the 3d group.

In the 5th second of ligation of the aorta, MCR and MRR increased by 33 and 22%, respec vely, in the 2d group, as compared to the control. In the 3d group of animals, we observed 24% slowing of heart rate, while the other parameters did not differ from control values. In the 4th group of rats, we failed to find deviations of parameters of contractility from the control. If we compare the parameters of contractility before ligation of the aorta and in the 5th s of

ligation, we shall find that the increment of strength parameters--rate of contraction is the most marked in the 3d group of animals (88-201%), followed by rats in the 1st group (39-138%), 4th group (29-139%) and, finally, 2d group (12-115%). The lowest increment of strength parameters--contraction rate in the last group is attributable to their higher baseline values.

Changes in parameters of cardiac contractility before and after denervation

Parameter	Animal group	With intact nervous regulation		After denervation		Postdenervation depression, %			
		before ligating aorta	5th s	before ligating aorta	5th s	before ligat.	P	5th s of lig	P
HR/min	1	269±19	223±8	173±11	168±6	26	<0,001	25	<0,01
	2	264±23	213±18	207±8*	179±14	22	—	16	—
	3	193±16*	170±10*	149±14	148±15	23	<0,01	13	—
	4	221±12	209±8	170±20	166±17	23	<0,01	21	<0,02
Pv, mm Hg	1	96±5	228±12	60±5,7	156±12	38	<0,001	32	<0,001
	2	107±7	230±11	96±12*	227±15*	10	--	1	--
	3	77±8	232±6	49±5,7	164±10	36	<0,01	29	<0,001
	4	96±6	237±10	63±7,2	173±22	36	<0,001	27	<0,05
MCR, mm Hg	1	5206±202	7 560±691	1571±190	3337±444	70	<0,001	56	<0,01
	2	6656±429*	10 072±558*	4544±1118*	6608±1076*	32	—	34	<0,05
	3	3566±444*	7 469±882	1240±155	3211±334	65	<0,001	57	<0,001
	4	5737±562	7 429±411	1[illegible]40±266	3780±372	70	<0,001	49	<0,01
MRR, mm Hg	1	2486±208	3 466±178	1206±221	1629±158	52	<0,001	53	<0,001
	2	3760±497*	4 200±224*	2469±408*	2552±228*	34	<0,05	39	<0,02
	3	1874±324	3 526±247	663±138	1669±282	61	<0,001	53	<0,001
	4	2309±165	3 126±168	1127±266	1427±196	51	<0,02	54	<0,001
IFS, mm Hg/mm Hg/mg dry tissue	1	162±13	334±33	67±6,9	168±14	59	<0,01	50	<0,001
	2	224±34	383±44	158±28*	327±53*	30		15	
	3	97±15	257±15	49±9,7	161±23	50	<0,05	37	<0,001
	4	140±11	320±21	67±7,5	176±22	52	<0,001	45	<0,01

*Difference is reliable in comparison to control.

After denervation, depression of parameters of myocardial contractility was observed at rest in all groups of animals, as compared to baseline data; however, the extent varied: in the 1st group of rats, HR, Pv, MCR, MRR and IFS were 26, 38, 70, 52 and 59% lower (data were processed by the method of differential variation statistics). In the 3d group, HR, Pv, MCR, MRR and IFS were 23, 36, 65, 61 and 50% lower, respectively, after denervation. In the 2d group, denervation of the heart did not elicit reliable changes in HR, as well as strength--rate of myocardial contraction; we merely observed a 34% decrease in rate of relaxation. Four-day coarctation of the aorta in the 4th group of rats was associated with decline of HR, Pv, MCR, MRR and IFS by 23, 36, 70, 51 and 52%, respectively. As can be seen from the submitted data, denervation led to depression of parameters of myocardial contractile function in control rats, as

well as intact and "hypokinetic" rats with coarctation of the aorta, to approximately the same extent, which is indicative of the important role of nervous influences, primarily adrenergic (isolated exclusion of vagi did not elicit any appreciable changes in contractile function) in regulation of cardiac activity in these animals. In the 2d group of rats, only MRR decreased under the effect of denervation, and there was no reliable change in the other parameters.

Depression of maximum parameters of contractile function in all groups of animals was demonstrated after denervation in the 5th second of ligation of the aorta, as well as in a state of relative physiological rest: HR, Pv, MCR, MRR and IFS decreased by 25, 32, 50, 53 and 50%, rexpectively, in the 1st group of animals, as compared to analogous parameters in the 5th s of ligation of the aorta with intact nervous regulation. In the 3d group, MCR, MRR and IFS diminished by 29, 57 and 37%, respectively. In the 2d group, MCR and MRR decreased by 34 and 39%, respectively. In the 4th group of rats, there was about the same extent of depression of maximum parameters of contractility after denervation as in control animals: HR, Pv, MCR, MRR and IFS were 21, 27, 49, 54 and 45% lower, respectively.

As we know, when the aorta is ligated, the increase in strength parameters--cardiac contraction rate is attributable mainly to activation of sympathetic influences. In our experiments, the degree of depression of contractility parameters in the 5s s of ligation of the aorta differed little in the 1st group, as well as 3d and 4th groups, which is indicative of the important and approximately equal role of the sympathetic level of nervous regulation of the heart in these animals. In the 2d group, HR, Pv and IFS did not change reliably after denervation, whereas rate of contraction and relaxation underwent less depression than in the other groups of animals.

The increase in afterload resistance in rats submitted to hypokinesia can be attributed to two mechanisms: as believed by many researchers [1-3, 7], long-term restriction of mobility elicits development of chronic stress in rats, in the course of which the heart adapts to stress factors and its resistance to repeated stress, such as the emergency phase of compensatory myocardial hyperfunction, increases; in the second place, as shown by data in the literature [6], the increase in cardiac contractile function during long-term hypokinesia occurs as a result of retardation in heart growth and increase in ratio of area of sarcolemma to cardiomyocyte volume. It can be assumed that a 4-day afterload on the hypokinetic heart stimulates its growth, normalizes the ratio of sarcolemma area to cardiomyocyte volume and contractile function of the myocardium. Indeed, 4-day coarctation of the aorta led to 22% increase in weight of the left ventricle ($p<0.05$) of the "hypokinetic" heart, and the hypokinetic heart acquired the capacity to react to adrenoblocking agents in the same way as the intact heart, as a result of the afterload.

Thus, the results of the experiments revealed the following: on the one hand, resistance of the heart of rats submitted to 60-day hypokinesia to a continuous 4-day after load was increased, as compared to intact animals with coarctation of the aorta; on the other hand, the afterload reduced the high contractile function caused by hypokinesia and brought it closer to the control level. In addition to nervous influences (sympathetic), intracardiac factors play an appreciable part in mechanisms of adaptation of the heart to hypokinesia and of the hypokinetic heart to an afterload.

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DISTINCTIONS OF PSYCHOSOMATIC CORRECTION OF PERFORMANCE DURING CONTINUOUS LONG-TERM WORK

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, Mar-Apr 87 (manuscript received 14 May 86) pp 59-62

[Article by A. I. Skrypnikov and A. K. Yepishkin]

[English abstract from source] It has been shown by experiment that autogenic training exerts a positive effect on the performance of operators working continuously for a long time. Their efficiency largely depends on their skill, current health state, and time of the day. Depending on these factors, autogenic training may increase the quality of operator's work by 7 to 49%.

[Text] In recent times, researchers have given close attention to methods of psychosomatic self-regulation as one of the promising directions in solving problems of correcting the condition of man. A variant of such methods, which has gained the broadest use, is autogenic training (AT), with which it is possible, according to data in the literature, to eliminate emotional tension and fatigue, to correct nocturnal sleep, activate efficiency, etc. [4-6].

In previous studies, we also observed that AT had a beneficial effect on functional state and work capacity of operators in a state of extreme fatigue [2, 3]. However, in a number of instances, its efficacy was lower than expected. The purpose of this study was to determine the factors that affect efficacy of AT.

Methods

We conducted 6 tests involving 56-72 hours of continuous work (CW) on 18 people 19-42 years of age who presented no deviations of health status. We simulated diverse operator tasks dealing with perception, information processing, decision making and implementation. The cyclogram of operator work was full, with minimal free time granted only to take meals and for personal hygiene, so that the operators became considerably tired already on the first day of the study.

The operators used AT every 6 h starting with the 1st h of work. The session lasting 15 min involved use of a standard AT tape recording. During this time, the control group of operators was given a break or allowed to sleep, as they wished.

Preliminary instruction on AT was offered by a method developed by L. P. Grimak [1], and it was aimed at removing tension and fatigue, activating reserve capacities with a set toward retaining efficiency for a long time. Specific parameters of heart rate and bioelectrical activity of the cerebral cortex served as the criterion of operator training [7]. The functional state of the operators was assessed in the course of the tests according to the EEG, which was recorded every 6 h during the work period.

All of the experimental data were submitted to statistical processing by conventional methods with use of Student's criterion.

Results and Discussion

We see from the data listed in the table that, on the whole, AT had a marked positive effect on efficiency in the simulated CW conditions: the results of operator work with AT use were considerably higher than in the control group. At the same time, analysis of experimental data within the sample revealed that efficacy of AT is largely determined by factors such as extent to which operators learned to use the method, their current functional state and time of day of AT.

Effect of AT on performance of operators under CW conditions ($M \pm \sigma$)

Type of activity	Parameters measured and units of measurement	Control group of operators	Operat. who used AT	Significance (P)
Compensatory tracking	(% error-free work)	74,4±3	87,7±2	<0,02
Sensorimotor compensatory tracking	(mismatch error in arbitrary units)	91,7±2	56,3±5	<0,05
Isolation of visual information from "noise":				
signal detection	(ms)	38,7±5	12,7±6	<0,02
signal identification	(% correct answers)	43,7±3	48,1±2	≤0,05
Sensorimotor response to audio stimulus	(ms)	238,8±7	209,7±6	<0,01

Figure 1 illustrates data pertaining to quality of sensorimotor tracking and dynamics of EEG rhythms in a well-trained operator[1] just before and just after an AT session. We see that the quality of performance improved from 61% of the baseline to 109%, i.e., by 49% ($P<0.01$). However, it did not exceed a mean of 30% in operators who underwent the usual 2-month training prior to the tests.

The stimulating effect of AT was manifested on the EEG in the form of increase in energy of β-rhythm to 130%, as compared to the baseline recorded before the session. The energy of rhythms of the slow EEG component decreased by 54% for Δ waves and 37% for Θ waves.

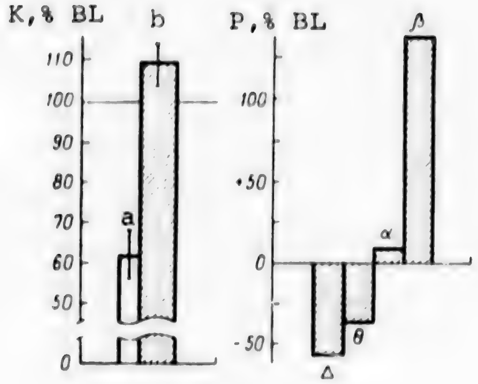

Figure 1.
Effect of AT on parameters of quality (K) of pursuit tracking and energy (P) of EEG rhythms
Here and in Figures 2 and 3:
a) data before AT
b) after AT
BL) baseline

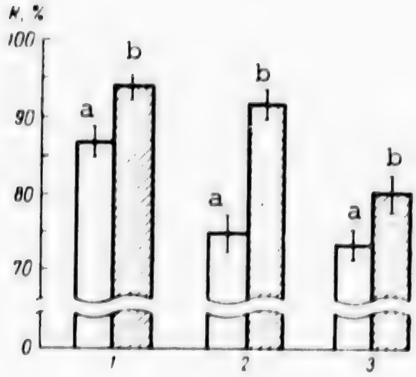

Figure 2.
Effect of AT on quality (K) of compensatory tracking at different stages of CW
1) first 12 h of study
2) second day of study
3) third day of study

In the operator's own account, he stated that fatigue and drowsiness disappeared after the AT session, a desire to continue with the work and interest in its end results appeared.

Maximum efficacy of AT was observed in all operators on the second day, and minimum for the first 12 h and at the end of the 3d day of the study. Thus, we see in Figure 2 that the quality of compensatory tracking improved by a mean to 20-25% ($P<0.02$) under the effect of AT on the 2d day, whereas at the start of the test it increased by only 5-7% ($P = 0.05$) and on the 3d day by 7-10% ($P<0.05$). The effect on the 2d day persisted for 5-6 h of subsequent work, but on the 3d day for no more than 1-1.5 h.

The insignificant increment in tracking quality after AT in the first hours of work can be attributed to absence in this period of psychophysiological conditions for manifestation of its effect. Most operators started the experiment with rather high work activity. There was virtually no "warm-up" period (the quality of performance did not diminish by more than 2-3% of the baseline). For this reason, no reliable differences were noted in dynamics of EEG rhythms before and after the AT sessions pursued in this time. The findings were somewhat different in operators who presented signs of emotional tension (increase in HR, in Θ-activity on the EEG and decrease in quality of performance) to some extent or other in the first few hours of the study. In this case, AT yielded a marked positive effect. After AT. the quality of performed operations rose to baseline values (±3%) with concurrent normalization of physiological parameters.

The insufficient efficacy of AT at the end of the 3d day is apparently related to the fact that, in the course of CW, there is depletion of the operators' psychophysiological reserves. Development of extreme fatigue was associated with significant prevalence of inhibitory processes over excitatory ones in the

central nervous system and extinction of dominant, activation of which with AT occurrs with some difficulty. It must be assumed that, for the same reason, AT pursued in the daytime is more efficacious than at night. Daytime AT (used from 0900 to 2100 hours) led to improvement of operator performance quality by a mean of 32% ($P<0.02$), and the EEG showed a decrease in energy of slow waves and increase in β activity (Figure 3). During the period of nocturnal sessions (from 2100 to 0900 hours) the quality of performance improved by a mean of 10% ($P\leqslant 0.05$) and, in general, it was at a lower level than in the daytime, even before AT. On the EEG, there were virtually no responses on the part of the rhythms under study, with the exception of insignificant (14%) increase in energy of β-waves.

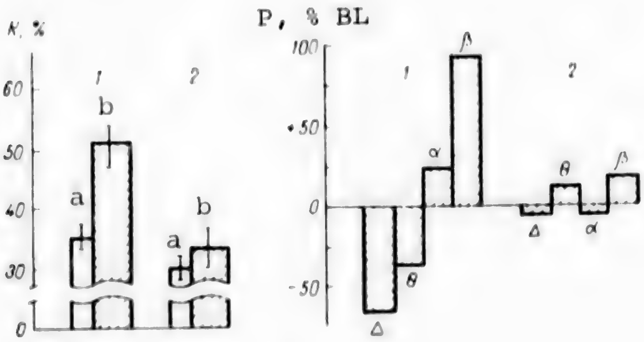

Figure 3.
Change in quality (K) of compensatory tracking and energy (P) of EEG waves under the effect of AT in the daytime (1) and at night (2)

Some operators, who also presented a low level of motivation, fell asleep during the night sessions. As a rule, the signs of central fatigue did not disappear after such sleep, on the contrary they increased. Subjectively, the operators assessed their condition as "tiredness," "listlessness," "apathy." Objectively, after such unsuccessful AT sessions we observed intensification of slow-wave activity on the EEG, as compared to parameters recorded just prior to AT.

We failed to observe reliable differences in qualitative parameters of performance in these subjects, as compared to the control group of operators, during this period. It should be assumed that, at night, fatigue is enhanced by the inactivating influence of the parasympathetic nervous system which, in turn, has an adverse effect on implementation of self-regulation skills.

It should, however, be noted that in spite of the relatively low efficacy of AT it would have been wrong to abandon it in a number of the above-mentioned cases. The parameters of quality of operator performance held at a stable level and even presented a tendency toward rising; on the average, they were 20-28% higher ($P<0.02$) throughout the test period than in the control group of operators.

The solution may be to use an optimum combination of AT with other ways and means of stimulation during the most stressful periods of time characterized by significant change in functional state and decline of operator work capacity. Moreover, the efficacy of AT could be enhanced by altering the procedure somewhat. It is known that virtually all modifications of psychosomatic regulation are described by three basic effects: calming, restoring and programming [4, 8]. When marked emotional stress is observed without signs of fatigue (in our case, this applied to some operators at the start of the study), it is necessary to lay emphasis on the first element of AT--calming. However, with significant

decrease in tonus of the cerebral cortex as a result of fatigue, when the first two elements of AT cause the subject to fall asleep and inactivate him, it is necessary to emphasize the third element of AT--"programming." The high results of performance during the entire test period in well-trained and highly motivated operators can serve as an example of this.

Thus, our studies enable us to assess more objectively the use of AT and to predict its efficacy in correcting the functional state and enhance efficiency of operators at different stages of continuous work.

FOOTNOTE

1. Subjects with many years of experience in using the method of psychosomatic regulation of their status in everyday life and at work were classified as well-trained.

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UDC: 612.843.53.014.45

INVESTIGATION OF CRITICAL FUSION FREQUENCY IN MAN DURING EXPOSURE TO NOISE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 27 May 86) pp 62-66

[Article by I. N. Dantsig and A. V. Diyev]

[English abstract from source] The critical frequency of flicker fusion in the central and four peripheral points of the retina was investigated in 12 test subjects, during and after one hour exposure to wide-band noise of 95 dBA. The subjects showed two types of response: three displayed an increase and nine a decrease of the flicker fusion critical frequency as compared to the control level. The changes showed individual variations. No correlation was found between the sign of changes in the parameter and its pretest level or the retinal site of registration.

[Text] Critical flicker fusion frequency (CFFF) characterizes functional lability of the visual analyzer, which is extremely important to evaluation of work performance in individuals in the operator professions. At the same time, development of space technology, aviation and the navy increases significantly the contigents of people exposed to noise. There are sparse and contradictory data in the literature concerning the effect of noise on CFFF. Some authors [8, 10] reported decline of CFFF under the effect of an acoustic stimulus, others observed a rise [6, 7], while others yet reported both types of reactions or their absence, depending on intensity of noise [1], combination of noise and vibration [3] and spectral characteristics of a photic stimulus [4]. The lack of opinion as to the nature and direction of changes in CFFF under the effect of noise served as grounds to conduct the following studies.

Methods

We conducted the studies under laboratory conditions with the participation of 12 men 20-25 years of age. Acoustic stimuli, in the form of monotone noise, were delivered through a headset from a white noise generator at 95 dBA intensity. Exposure lasted 60 min. CFFF was examined using a device assembled on the basis of a PRP-60 projection perimeter. Three AL-307A light-emitting diodes (birghtness 4 $\mu cd/cm^2$, emission wavelength 560 nm, diameter 5 mm) were used as test stimuli, one of which was placed in the center of the perimeter arc, the two others 25° to the right and left of center. Flicker frequency of the light-emitting diode was set by a low-frequency pulse generator in the range of

0-50 Hz. Upon reaching the critical frequency, the subject depressed the "response" button, as a result of which the frequency meter connected to the master oscillator was actuated. Frequency measurements were accurate to 1 Hz. The subject's eyes were 333 mm away from the arc of the perimeter in the plane traversing its center. Arc brightness was matched to equivalent illumination of the room at the subject's eye level. The tests began after 45-min adaptation to ambient illumination. CFFF was measured monocularly for the right eye at 5 points on the retina (in the center and at the 25th° of 0, 90, 180, 270 meridians), 3 times at each point; the left eye was covered with a soft patch during the tests. When testing the peripheral retinal points, the subject fixed his gaze on the central light-emitting diode, which served as the fixation point. CFFF was recorded before, during and for 60 min after exposure at 15-min intervals. In all we conducted 129 tests, 67 with exposure to noise and 62 control tests.

Results and Discussion

Primary analysis of the results revealed that there were very wide individual differences in CFFF threshold. Thus, in the baseline sample, CFFF of the central retinal region ranged from 15 to 38 Hz, and at other tested points of the retina, from 10 to 35 Hz. Several authors have reported the wide scatter of individual CFFF thresholds [2, 5, 9, 11]. At the same time, the fluctuations in CFFFF obtained according to baseline data did not exceed 5 Hz in the same subject when rechecked. Analysis of the data obtained during exposure to the acoustic stimulus revealed that, as a result of this factor, there was substantial change in functional lability of the visual analyzer. The quantative and qualitative characteristics of the demonstrated changes also presented individual differences in each subject. At the same time, we failed to demonstrate an overt dependence of CFFF dynamics during exposure to noise on baseline CFFF level. For this reason, a definitive evaluation of results was made on the basis of averaged change in relation to the baseline for each experiment, since processing data according to absolute values, even with consideration of the direction of change, increased the scatter significantly, and this inevitably led to smoothing of demonstrated changes. As a result of grouping results according to averaged CFFF deviations in relation to the baseline level, we singled out two groups of subjects with opposite directions of responses to noise. It should however, be noted that analysis of data from this control series of tests failed to demonstrate differences in CFFF dynamics in the course of a 120-min test without noise between subjects in these two groups, so that we did not have to divide subjects into analogous groups in the control series.

The figure illustrates the averaged CFFF changes in relation to the baseline, which were obtained with exposure to an acoustic stimulus, as well as in the control series of experiments.

We put 3 subjects who showed elevation of CFFF in response to an inadequate stimlus (14 experiments with stimulation and 14 without) into the first group (type I response). The second group (type II reaction) consisted of 9 subjects who presented a decline of CFFF (53 tests with exposure and 48 without).

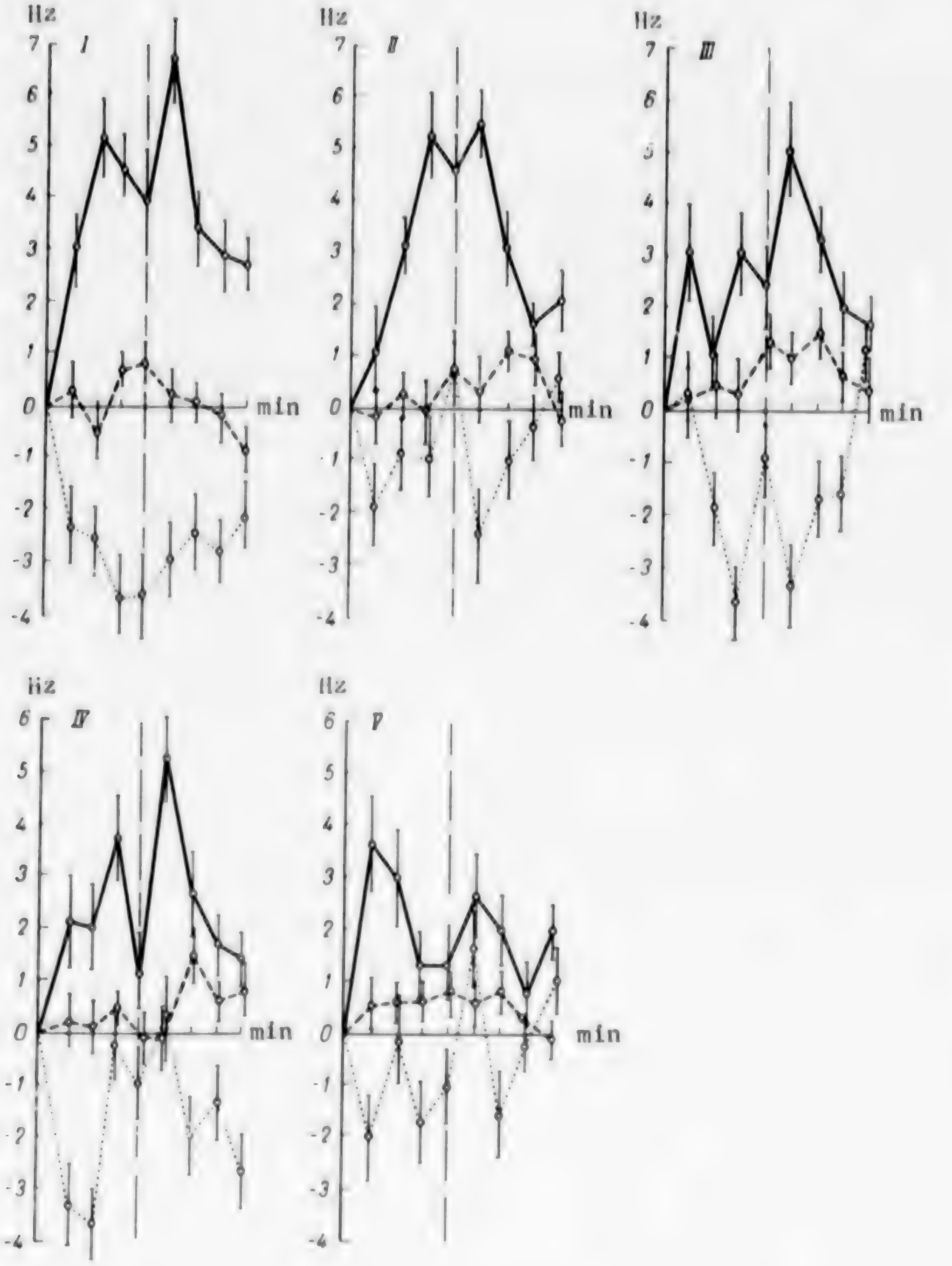
As can be seen from the submitted data, there was no basic difference in direction of observed changes as a function of point where CFFF was measured on the retina. A distinction inherent in the first type of response to noise was an increase in

CFFF, in relation to the baseline, throughout the exposure period, and this was the most marked in the central and lateral (180°) regions of the retina, with maximum change of 5.5 Hz. In the other tested retinal points, the maximum change in CFFF did not exceed 3 Hz. By the end of the exposure period (60 min), CFFF diminished somewhat at all tested points without, however, reaching the baseline. At the same time, 15 min after exposure to noise there was a dramatic increase in critical frequency simultaneously in all tested points. Maximum increase was observed in the center of the retina, where it was 6.7 Hz higher than the baseline. By the end of the experiment, CFFF did not revert to the baseline either in the center or peripheral retions of the retina.

The second type of response to noise was characterized by decline of CFFF at all tested points of the retina, and it was the most marked in the central, medial (0°) and inferior (270°) points, the difference being more than 3 Hz. By the end of the exposure period (60 min), there was an increase in CFFF at all tested points, which was marked in the peripheral regions of the retina and barely perceptible in the center. We observed further increase in CFFF 15 min after exposure to noise in the central, superior (90°) and inferior (270°) points of the retina, and in the last two points CFFF exceeded the baseline, whereas in the medial (0°) and lateral (180°) points, on the contrary, we observed significant decrease in CFFF, as compared to the baseline value. CFFF 60 min after exposure to noise was at a lower level in the central and inferior (270°) regions of the retina than before the experiment, whereas in the medial (0°), superior (90°) and lateral (180°) regions, on the contrary, it exceeded the baseline level.

In the control series of studies, the fluctuations of CFFF in the course of a 2-h observation period virtually failed to exceed 1 Hz, regardless of the point of recording CFFF on the retina. A comparison of the changes in CFFF during exposure to noise in both groups of subjects to the results obtained in the control series revealed that the acoustic stimulus had a marked effect, considering that there were extraneous factors present during the experiment.

Thus, acoustic stimulation elicits a marked change in lability of the visual analyzer; at the same time, the direction of these changes depends on a person's individual properties. It should be noted that when we compared our findings to the results of studies conducted by other authors there was only partial coincidence of results. Thus, the studies of V. M. Birinskiy [1], whose experimental conditions were the closest to our (98 dB A noise, exposure time 1 h) established merely a decline of CFFF in response to acoustic stimulation, which corresponds to the second type of response in our tests. According to S. V. Kravkov [6, 7], exposure to noise leads to rise of CFFF in the center of the retina and decline on the periphera which, in the opinion of the cited author, is attributable to reciprocal inhibition. However, in our studies there was no manifestation of reciprocity between central and peirpheral regions of the retina; the change in CFFF at all tested points was in the same direction. The increase in CFFF demonstrated by the author in the center of the retina is consistent with our data for the first type of response. It is the most difficult to make a comparative assessment of test results with respect to data obtained under industrial conditions [3, 8] where, as we know, in addition to noise, there are several factors, each of which can have an appreciable influence on CFFF dynamics in workers. It can be assumed that the existence of individual reactivity to noise is the cause of some discrepancy between our



Dynamics of CFFF in different regions of the retina during exposure to noise X-axis, time of exposure and aftereffect (measurements every 15 min; vertical dash line--termination of exposure); y-axis, CFFF change in relation to baseline, Hz. Boldface line--type I reaction; dot-dash line--type II reaction; dotted line--control. Regions of the retina: I) central, II) lateral, III) medial, IV) inferior, V) superior

results and data obtained by other authors. In this respect, it is significant that S. V. Kravkov [7] observed atypical effects in some subjects in response to acoustic stimulation; however, he interpreted this fact as a rare case of reactivity to sounds. At the same time, the studies pursued b L. A. Shvarts [11] demonstrated that the direction of changes in some visual functions under the effect of noise depends to a significant extent on individual distinctions of subjects and state of their central nervous system at the time of the tests. Our data warrant the statement that the direction of changes in CFFF under the effect of an acoustic stimulus also depends on individual distinctions of subjects. This is convincingly confirmed by the fact that repeated testing of the same subject yielded qualitatively homogeneous results. However, we failed to establish a correlation between baseline CFFF and direction of change, so that we are unable to assess the influence of functional state of the central nervous system on results of exposure. Similarly, it was not deemed feasible to demonstrate individual differences in extent of change. At the same time, the causes of differences in extent of change at different points of the retina are incomprehensible, i.e., difference in resistance of central and peripheral regions of the retina to acoustic stimuli. Unfortunately, we do not know the possible neurophysiological bases for such a phenomenon.

Thus, in assessing the functional state of operators when they are exposed to noise by measuring CFFF, one should expect appearance of ambiguous reactions, the direction of which most probably depends on individual distinctions of the central nervous system. In this regard, one should pay special attention to the need to take into consideration individual differences when measuring CFFF thresholds, since mechanical averaging of findings could lead to distortion of the real situation, and the end result would depend on the random correlation between individual reactions of subjects included in the sample.

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DYNAMICS OF NONCOLLAGEN PROTEIN METABOLISM IN DOGS EXPOSED TO LOW DOSES OF CHRONIC GAMMA RADIATION FOR SIX YEARS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 27 May 86) pp 66-69

[Article by Z. A. Vinogradova]

[English abstract from source] The effect of chronic and acute (as compared to the total dose) gamma-irradiation in the range 2.5-7.5 Gy on metabolism of noncollagen proteins (NCP) in various tissues and peripheral blood of dogs was investigated. Metabolic disorders of NCPs in tissues were found. Their high level was indicative of enhanced collagen formation in the irradiated animals. With respect to the NCP content 3 to 14 days after acute irradiation in the dose 0.42 Gy there was a change in the body which was independent of the total irradiation dose.

[Text]Man is exposed to a set of factors during spaceflights (weightlessness, accelerations, vibration, high level of ionizing radiation, etc.), which could lead to certain morphological changes in organs and tissues, demineralization of some skeletal bones with processes of replacement of cartilage by bone structures [2, 3].

Animal experiments have shown that decalcification of bone tissue, irreversible loss of calcium and its redistribution in other tissues occur after exposure to radiation in a dosage of 0.4 Gy [10]. Authors relate these distinctions of mineral metabolism following irradiation to changes in metabolism of noncollagen proteins (NCP). In the opinion of some researchers [1, 5], metabolism of connective tissue NCP is one of the important factors in implementing the body's adaptive reactions. Changes in it lead to impairment of fluid-electrolyte and organic composition of tissue; in particular, the mechanism of fixing calcium in bone, cartilage, as well as connective tissue of other organs, is affected.

We submit here the results of a study of NCP metabolism in different organs and tissues, as well as in peripheral blood, of dogs submitted to chronic irradiation in low doses.

Table 1. Dynamics of relative ($X \pm 2.7\ \sigma_x$) NCP content in connective tissue of various canine organs under normal conditions and with chronic exposure to γ-radiation

Tissue or organ	Duration of exposure, years									
	2		3		4		5		6	
	2.50 Gy	control	3.75 Gy	control	5.00 Gy	control	6.25 Gy	control	7.50 Gy	control
Lungs	17,0±2,9*	4,4±1,3	18,1±2,9*	7,1±1,3	18,7±3,0*	9,3±1,3	19,2±3,0*	11,5±1,3	20,3±3,0*	13,7±1,3
Aorta	12,6±1,3	13,7±4,3	13,7±1,3	14,3±4,3	14,3±1,3	14,3±4,3	15,4±1,3	14,8±4,3	16,5±4,0	14,8±4,3
Liver	10,4±1,3	8,8±1,3	11,5±1,3	9,9±1,3	12,6±3,0	11,0±3,0	14,3±3,0	12,1±4,3	15,4±3,0	13,2±3,0
Cartilage	19,0±4,3*	12,5±1,3	20,3±4,3*	13,2±1,3	21,4±1,3	13,2±1,3*	22,0±6,0*	13,7±1,3*	22,5±6,0*	14,3±1,3
Skin	14,8±2,9*	9,9±1,3	15,4±3,0*	9,9±1,3	15,9±3,0*	9,9±1,4	16,5±3,0*	10,4±1,3	17,0±3,0*	10,4±1,3
Elastic ligament	7,7±1,3*	11,5±1,3	9,9±3,0	11,5±1,3	12,1±3,0	12,1±1,3	14,3±4,3	12,3±1,3	16,5±4,3	12,6±1,3

*$P<0.05$, here and in Table 2.

Methods

Experiments were performed on 58 dogs which were 1 to 3 years old before the start of irradiation. Irradiation and upkeep conditions were described in detail previously [4]. The animals were exposed to chronic γ-radiation at a dose rate of 0.0017 Gy/day (cumulative dosage 1.25 Gy/year). Cumulative absorbed doses constituted 2.50, 3.75, 5.00, 6.25 and 7.50 Gy after 2, 3, 4, 5 and 6 years, respectively. NCP metabolism was examined in the lungs, aorta, liver, cartilage, skin and elastic ligament. NCP of peripheral blood was assayed after acute exposure in a dose of 0.42 Gy following accumulated doses of chronic radiation, when cumulative absorbed tissue doses constituted 5.90 to 11.20 Gy.

NCP content was calculated using the following formula:

$$NCP = \frac{\text{tyrosine} - \left(\text{hydroxyproline} \times \frac{0.6}{13.6}\right)}{5.5} \times 100$$

This formula was derived on the basis of 0.6% tyrosine in collagen and a mean of 5.5% in NCP, with 13.6% hydroxyproline in collagen [13]. Hydroxyproline and tyrosine were assayed by conventional methods [11, 12]. A group of nonirradiated animals tested concurrently with irradiated ones served as a control. The results were submitted to statistical processing with use of Student's criterion. All quantitative data are given in micromoles per gram dry tissue weight and micromoles per milliliter peripheral blood.

Results and Discussion

Our studies enabled us to demonstrate age-related dynamics of NCP metabolism in different canine tissues (Table 1, control group).

Thus, in 6 years NCP content increased 3-4-fold in the lungs, and by 20-30%

in the liver and cartilaginous tissue. No reliable changes were demonstrable in the aorta, skin and elastic ligament.

The findings are indicative of specific dynamics of NCP metabolism, which is a function of type of tissue and age of the animals. During the aging process, change in NCP equilibrium leads to certain changes in physiological functions of organs and tissues [7].

Investigation of the dynamics of NCP metabolism in tissues of dogs submitted to chronic irradiation (cumulative dose 1.25 Gy per year) enabled us to demonstrate the reaction of these proteins to radiation. The level of the tested parameter rose in the lungs, cartilage and skin after exposure to radiation for 2 years, as compared to the control. By this time, cumulative tissue dose was 2.5 Gy. Thereafter (cumulative doses of 3.75 and 7.50 Gy, respectively), NCP concentration held at a high level. Their levels in the aorta, liver and elastic ligament of irradiated animals did not differ from the control.

Table 2. Dynamics of relative NCP content ($X \pm 2.7\ \sigma_x$) in peripheral blood of dogs following acute exposure to radiation in a dosage of 0.42 Gy against the background of chronic irradiation

Dose, Gy	Time of testing, days					
	1	3	7	14	21	28
5.90	60.5±5.2	81.0±19.0*	74.4±4.0*	81.9±5.5*	--	*
9.30	57.8±10.0	73.6±12.0*	78.8±4.0*	50.4±26.0	--	54.4±10.0
Control (no radiation)	52.9±14.0	62.5±11.0	53.4±3.0	56.5±20.0	—	56.8±8.0
7.10	74.0±15.0	61.1±26.0	102.0±11.0	76.0±16.0	68.6±28.0	58.5±9.0
11.20	56.4±31.0	84.0±28.0*	101.0±14.0	68.5±24.0	65.5±21.0	60.6±12.0
Control (no radiation)	65.5±21.1	55.4±13.0	77.1±26.0	70.0±11.0	73.6±8.0	49.4±11.2

Being the most active connective tissue proteins, NCP participate in fibril formation, aggregation of collagen fibers and their primary fixation of calcium. The elevated NCP level in tested organs during chronic irradiation (1.25 Gy/year) may be indicative of intensification of collagen-forming processes. Pathoanatomical studies of irradiated animals revealed accumulation of mucoid substances of connective tissue, which determines its physicochemical properties. Impairment of metabolic processes, in particular with reference to NCP, is the basis for accumulation of mucoid substances [6, 9].

Investigation of NCP content of canine peripheral blood after single exposure to radiation in a dosage of 0.42 Gy revealed (Table 2) that their level reaches a maximum with reliable significance within 3-14 days after acute exposure, and this does not depend on the accumulated radiation dose (5.90-11.20 Gy).

Thus, while maximum NCP content was demonstrable on the 3d-14th day after acute irradiation in a dosage of 0.42 Gy (with accumulated dose of 5.90 Gy) and it ranged from 81.0±19.0 to 81.9±5.5 (versus 62.5±11.0 to 56.5±20.0 in the control group), with a cumulative dosage of 11.20 Gy it ranged from 84.0±28.0 to 101±14.0 (55.4±13.0 to 77.1±26.0 in the control) at the indicated test times. Thereafter, on the 21st and 28th days of testing the animals, the values in experimental groups did not differ from the control.

In view of the fact that NCP are among the important factors in implementing homeostasis of connective tissue, in particular, their relation to mineral and fluid-electrolyte metabolism, it can be assumed that the high level of their metabolism in the course of 6 years of exposure to radiation is indicative of compensatory and adaptive processes in the body in response to ionizing radiation in the tested range of doses. The high NCP level in canine blood on the 3d and 14th days after acute irradiation against the background of chronic irradiation serves to confirm our assumptions. It is necessary to mention here that the level of the response to acute irradiation did not change as the cumulative radiation dose increases. Consequently, it can be assumed that there may be a certain threshold to the action of ionizing radiation on metabolism of connective tissue proteins.

All of the foregoing indicates that chronic exposure of dogs to low doses of radiation stimulates NCP metabolism in all tested tissues. On the basis of the obtained data, it can also be assumed that mineral metabolism may also be impaired during long-term spaceflights due to ionizing radiation [2, 8, 10].

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CALCULATION OF IONIZING RADIATION LEVELS ALONG TRAJECTORIES OF HIGH-ALTITUDE FLIGHTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 26 Nov 85) pp 69-73

[Article by Yu. I. Barannikov, O. A. Barsukov, and P. F. Gavrilov]

[English abstract from source] This paper presents estimates of ionizing radiations in the earth's atmosphere obtained by calculating primary cosmic ration passing through it. The contribution of protons with energies of up to 200 MeV and neutrons with energies of 0.1 to 100 MeV to the equivalent dose rate produced by fluxes of ionizing radiations of cosmic origin amounts to 90%. The contribution of electrons and gamma-rays is one order of magnitude smaller and the contribution of muons and pions is negligibly small. The paper gives data about the altitude and latitude distribution of equivalent dose rates generated by fluxes of galactic and solar cosmic rays. The dose rate level reaches its maximum at altitudes of about 20 km and in the regions situated to the North of 67° N.1.

[Text] The attitude toward the problem of effects of naturally occurring radiation on man has changed in recent years [1].

Development of new equipment and technology leads to additional exposure of people to radiation. For example, high-altitude transport aircraft began to be used to transport passengers, and during flights aboard such aircraft man is deprived of natural protection against solar and cosmic radiation in the form of the layer of air in earth's atmosphere (at sea level, thickness of this air shield is about 1000 g/cm^2, it is 250 g/cm^2 at an altitude of 10 km, 50 g/cm^2 at 25 km and 5 g/cm^2 at 35 km).

The cruising altitude of IL-62 and TU-154 flights is 10-12 km, and modifications of these aircraft will lead to a cruising altitude of 14 km. As reported in the foreign press, supersonic transport aircraft fly at altitudes of 18-20 km; the second generation of such aircraft being developed at the present time will fly at 30-35 km. This means that flights aboard high-altitude transport aircraft occur in the presence of radiation conditions that differ appreciably from those on the ground, and this must be taken into consideration in assessing the total radiation dose to which man is exposed [1, 4].

This additional burden is due to the radiation conditions over the trajectory of aircraft flight, which are characterized by equivalent dose rate generated by the flux of cosmic rays in the atmosphere. In order to assess the radia tion conditions on any possible trajectory of flight, it is necessary to know the spectral and angular characteristics of the basic components of cosmic rays in the atmosphere, their dependence on altitude and latitude. There is information in the Soviet and foreign literature [3, 4, 10, 11] concerning the radiation properties of cosmic ray flux in the atmosphere; however, it is difficult to make practical use of published data (for example, to assess the radiation conditions over a concrete trajectory of a high-altitude aircraft) because this information is scattered and fragmentary.

We submit here the results of calculating dose fields formed by the main components of cosmic rays at altitudes of 10-30 km and latitudes of 0-90° north lat. during calm geophysical conditions and during solar flares.

Methods

Equivalent dose rate P generated by fluxes of different types of ionizing radiation with different spectral-angular distribution is found using the formula:

$$P = \sum_i \int_E \int_\Omega k_i(E) \cdot I_i(E, \Omega)\, d\Omega\, dE, \tag{1}$$

where index i refers to the type of ionizing radiation, $I_i(E, \Omega)$ and $k_i(E)$ is spectral-angular distribution and regulated transition from the flux of ionizing particles of the ith type as a function of equivalent dose rate they generate.

To assess radiation conditions on any trajectory of aircraft flight, it is necessary to determine the levels of equivalent dose rate $P(h, \varphi)$ (equivalent dose rate generated by the flux of the ith component of cosmic rays in the atmosphere at altitude h and latitude φ), i.e., qualitative composition and spectral-angular characteristics of cosmic ray flux in the region of h = 10-30 km and φ = 0-90° north lat. To obtain these characteristics of ionizing radiation flux in the atmosphere, we solved the problem of mathematical modeling of passage of primary cosmic rays in earth's atmosphere.

The system of equations describing the process of dissemination of cosmic rays in the atmosphere can be written down as follows [3]:

$$dI_i(E, \Omega, h)/dh = -A_i - B_i + \Sigma C_{ij} + \Sigma D_{ij} - \frac{\delta}{\delta E}[f_i(E) \cdot I_i(E, \Omega, h)], \tag{2}$$

where h is depth of atmosphere (g/cm^2), $I_i(E, \Omega, h)$ is differential density of flux of ionizing particles of the ith type; A_i, D_{ij}, f_i takes into consideration elimination of particles of the ith type due to interaction with atmospheric substance; B_i is decay of particles of the ith type if they are unstable;

C_{ij} is increase in flux of particles of ith type due to interaction between those of the ith type and atmospheric substance; D_{ij} is decay of particles of jth type if they are unstable, with formation of particles of the ith type, and f_i is energy loss of particles of the ith type.

In the calculations, the atmosphere was rendered in the form of a flat layer (point h = 0 corresponds to its top range) with the following chemical composition: oxygen 21.5%, nitrogen 78.5%. Distribution of gas in the vertical plane corresponds to a model of standard atmosphere.

In calculating equivalent dose rate generated by flux of cosmic rays in the atmosphere, we took into consideration the contribution of proton flux at energy of 30 MeV to 1 GeV, netrons at energy ranging from thermal to 1 GeV, electrons and γ-rays with energy of 1 MeV to 1 GeV. The choice of these energy ranges was based on the following considerations: a) the bottom range corresponds to minimal energy to provide a range for an ionizing particle in aluminum in excess of 1 g/cm^2 (typical thickness of transport aircraft fuselage); b) at altitudes of up to 30 km above sea level, the intensity of cosmic rays with energy in excess of 1 GeV constitutes less than 5-7% of total intensity of ionizing radiation, which (in view of the low coefficient of quality of radiation at such energy levels) allows us to disregard their contribution to formation of dose fields in the atmosphere at such altitudes and compensate this assumption by increasing the intensity of ionizing radiation flux at energy of up to 1 GeV to such an extent as to satisfy the following equation:

$$\int_{E_{min}}^{\infty} I_i(E)\,dE = \int_{E_{min}}^{1\ \mathrm{GeV}} I_i'(E)\,dE,$$

where $I_i'(E) = \alpha \cdot I_i(E)$ for energy under

1 GeV, while $I_i(E)$ is the energy spectrum of ionizing particles of the ith type and α is a constant coefficient.

The flux of cosmic ray nuclei I_z is viewed as an additional flux of protons with intensity $z \cdot I_z$ and flux of neutrons with intensity $(A - z) \cdot I_z$, where I_z is intensity of flux of cosmic ray nuclei with charge z and atomic number A. We assumed that the qualitative composition of cosmic rays on the boundary of the atmosphere would be as follows [3, 6]:

$$I_p : I_\alpha : I_L : I_M : I_H = 1300:94:2:7:4$$

where I_p is intensity of proton flux, I_α is the same for α particles, I_L, I_M and I_H is the same for nuclei in groups L(z=3-5), M(z=6-9) and H($z \geqslant 10$), respectively.

The system of equations (2) was solved by mathematical methods on a computer. Boundary conditions for its solution were determined by the spectrum of primary cosmic rays on the boundary of earth's atmosphere and rigidity of geomagnetic cut-off at the sought point, i.e., latitude of the site.

The spectrum of primary cosmic rays was given in the following forms:

$$I(E) = I_0 \cdot E^{-2,65} (1 - 0,6/\sqrt{E})$$

for flux of galactic cosmic rays (GCR), where E is total particle energy;

$$I(E) = I_0 \cdot E^{-\gamma}, \gamma = 2, 3, 4, 5, 6 \text{ and}$$
$$I(R) = I_0 \cdot \exp(-R/R_0), \; R_0 = 100 - 500 \text{ MV}$$

for flux of solar cosmic rays (SCR), where γ is a parameter of the SCR spectrum and R_0 is characteristic hardness of SCR protons for each flare. By combining these two expressions for the spectrum of solar protons, we can obtain the spectrum of solar proton flux I(E) during any real SCR event:

$$I(E) = \sum_i a_i E^{-\gamma_i} + b_i \exp(-R/R_{0i}),$$

where $R = \sqrt{(E^2 - m_p^2)/c^2}$,

while a_i and b_i are constants, c is speed of light.

Angular distribution of comic ray fluxes on the boundary of the atmosphere was considered to be isotropic.

Vertical hardness of geomagnetic cut-off R_0, which determined the lower range of the energy spectrum of cosmic rays, was calculated using the following formula:

$$R_0 = M_3 \cos^4 \lambda / 4R_3,$$

where M_3 and R_3 are magnetic moment and earth's radius, λ is geomagnetic latitude. For particles with other than vertical direction of movement, hardness was determined using the following equation [6, 9]:

$$R(\theta, \varphi) = 4R_0/(1 +$$
$$+ \sqrt{1 - (R_0/14,9)\, 3,4 \cdot \sin\theta \cdot \cos\varphi})^2,$$

where Θ and φ are zenith and azimuth angles of particle movement.

Separate calculations were made for nucleon and electron-photon components of cosmic rays, and the latter was not considered in passage of the nucleon component in the atmosphere. Ionization losses of charged particles were calculated using the well-known formula of Bethe-Block [2, 9]. The section of nonelastic nuclear interaction of nucleons with nuclei of atoms of nitrogen and oxygen in the range of tested energy showed virtually no change, and for this reason was considered constant.

Dual differential cross-sections of formation of secondary nucleons in nucleon-nuclear interactions required to obtain spectra and angular characteristics of nucleons in the atmosphere were approximated by means of the semi-empirical

formulas of Serov-Sychev [8], which enabled us to lower significantly the computer requirements (speed, memory, etc.). Vast experimental material was gathered concerning interaction between nucleons and nuclei of Be, C, O, Al, and semi-empirical formulas were checked, which revealed that they conformed well with the experimental data.

The regulated transition from flux of ionizing particles as a function of the equivalent dose rate they generated was taken from [5, 7].

Results and Discussion

Figure 1 illustrates the level of equivalent dose rate generated by fluxes with different GCR components in the atmosphere at an altitude of 16 km (100 g/cm^2 residual atmosphere) for the northern hemisphere. Overall equivalent dose rate is largely a function of latitude, and the maximum is referable to the region north of 57° north lat., and north of 67° north lat. it is virtually constant with a value of 3×10^{-5} Sv/h.

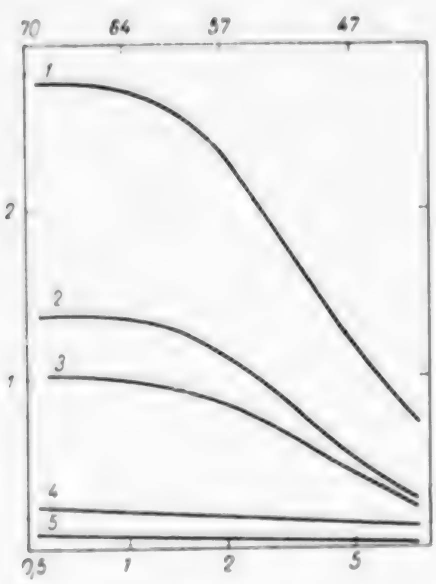

Figure 1.
Equivalent dose rate generated by flux of different components of GCR in earth's atmosphere at an altitude of 16 km as a function of local latitude
X-axis: top, latitude (°), bottom, harness of geomagnetic cut-off (GV); y-axis: equivalent dose rate ($Sv/h\cdot10^{-5}$). Here and in Figure 2:
1) equivalent dose rate generated by overall flux of ionizing radiation
2-5) the same by fluxes of neutrons, protons, electrons and γ-rays, respectively

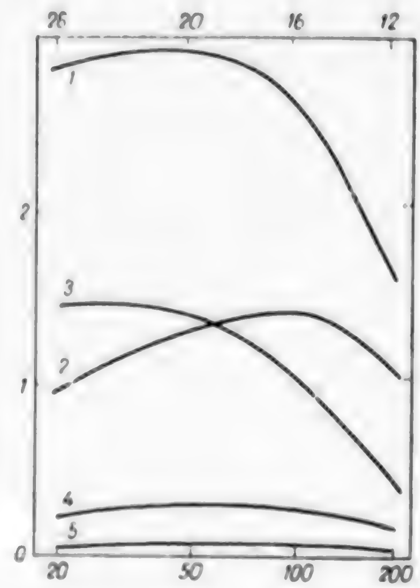

Figure 2.
Equivalent dose rate generated by flux of different components of GCR in earth's atmosphere in the region north of 67° north lat. as a function of altitude above sea level (depth of residual atmosphere)
X-axis, top, altitude above sea level (km), bottom, depth of residual atmosphere (g/cm); y-axis, equivalent dose rate ($Sv/h\cdot10^5$)

Figure 2 illustrates distribution of equivalent dose rate generated by fluxes of different components of GCR in the atmosphere in a zone north of 67° north lat. as a function of altitude. Maximum equivalent dose rate levels are observed at about 20 km altitude; fluxes of neutrons are of deciding significance at altitudes below 20 km and proton flux, at above 20 km.

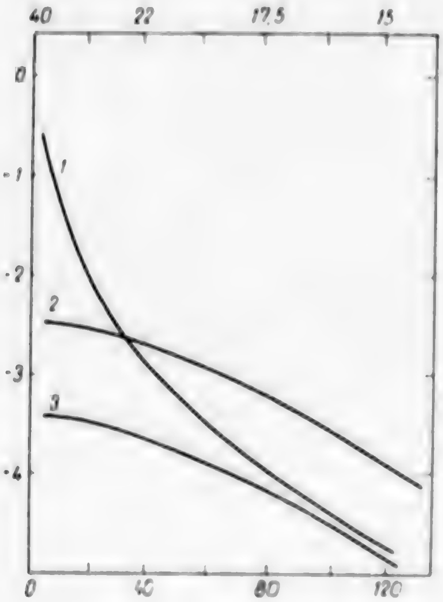

Figure 3.
Equivalent dose rate generated by SCR flux in the atmosphere in the zone north of 67° north lat as a function of altitude (depth of residual atmosphere)

X-axis: top, altitude (km), bottom, depth of residual atmosphere (g/cm^2); y-axis, logarithm of dose rate (in relative units)

1, 2) equivalent dose rate generated by proton and neutron flux, respectively
3) absorbed dose rate generated by neutron flux

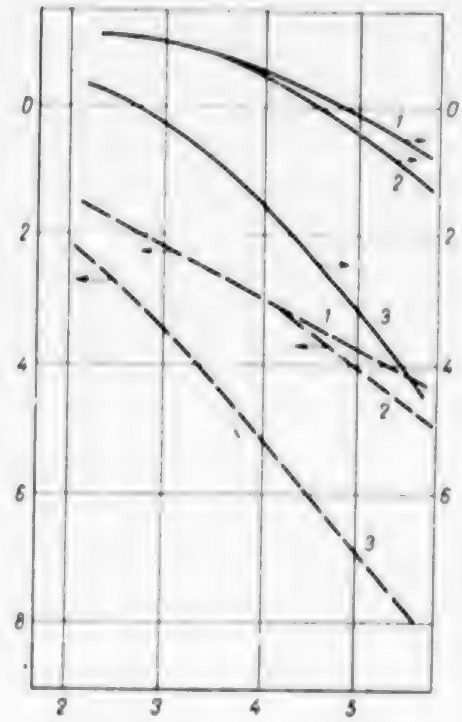

Figure 4.
Equivalent dose rate and intensity of ionizing radiation in atmosphere as a function of parameter of SCR spectrum

X-axis, parameter of SCR spectrum (μg); y-axis: left, log (I/I_0) (dash line), right, log (P/I_0), mrem/h·cm^2·s (boldface lines); I_0--SCR proton flux at boundary of atmosphere, I and P--total flux of ionizing radiation and equivalent dose rate generated at 16 km. 1-3--0.05, 1 and 5 GV, respectively

As can be seen in Figures 1 and 2, overall equivalent dose rate generated by fluxes of different GCR components in the atmosphere is about 90% attributable to fluxes of protons and neutrons; the share of electron and γ-ray fluxes did not exceed 10% and that of muons and pions, 1% (not shown in the Figures).

Distribution of equivalent dose rate as a function of particle energy is as follows: 90% of the equivalent dose rate generated by proton flux is attributable to particles with energy of up to 200 MeV, 35% of the equivalent dose rate generated by neutron flux, to particles with energy of 1-10 MeV, 60% to particles

with energy of 10 MeV to 1 GeV. Distribution of doses over energy intervals of particles is a rather weak function of latitude of the region, and it is relevant only at absolute values for equivalent dose rate (changes do not exceed 10%).

Figure 3 illustrates altitude distribution of equivalent dose rate (in relative units) generated by SCR flux in the atmosphere north of 67° north lat. The spectrum of SCR is exponential, R_0 = 125 MV. At altitudes up to 20 km, the equivalent dose rate is determined mainly by neutron flux and above 20 km, by proton flux.

Latitude as a function of equivalent dose rate generated by SCR flux in the atmosphere is considerably more relevant than for dose rate generated by GCR flux. This is due to the fact that the energy of SCR protons does not exceed several hundred megaelectronvolts and their penetration into earth's atmosphere is limited to 60° north lat. In zones north of 67° north lat, equivalent dose rate of SCR is virtually constant; at about 60° north lat there is a virtually exponential drop to zero.

Figure 4 shows equivalent dose rate generated by SCR flux as a function of spectrum parameter γ. The results were obtained for a single SCR flux on the boundary of the atmosphere. We see that it is a strong function of γ; when γ changes by one unit, equivalent dose rate changes by more than one order of magnitude.

Using the above results of altitude and latitude distribution of equivalent dose rate generated by fluxes of cosmic rays in earth's atmosphere, we can assess their radiation effect on man during flights aboard high-altitude aircraft:

$$D=\int_T P[h(t),\varphi(t)]\,dt,$$

where D is overall equivalent dose rate received by man aboard a high-altitude aircraft over the entire flight, T is overall flight time, $h(t)$ and $\varphi(t)$ are the altitude and latitude profiles, respectively, of the flight trajectory.

Thus, the equivalent dose rate generated by ionizing radiation of cosmic origin is a strong function of latitude of the region, type and energy of particles. Special mention should be made of the fact that the contribution of neutrons to overall equivalent dose rate at aircraft flying altitudes is either predominant or comparable to the contribution of protons (whereas protons make the main contribution to dose in near-earth space). This is of some importance to development of onboard dosimetric instruments, and they should be furnished primarily for aircraft, the trajectory of which passes into the zone north of 57° north lat.

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MATHEMATICAL MODEL OF PILOT HEAD KINEMATICS DURING EJECTION INTO AIR FLOW

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 27 Aug 86) pp 73-78

[Article by V. I. Kharchenko, N. V. Golovleva, Yu. G. Konakhevich, V. A. Lyapin, A. V. Maryin, V. Kh. Petlyuk, and L. N. Shollo]

[English abstract from source] The trajectories of head movements in the helmet and velocities of impact contact with the seat and interior of the cockpit were calculated as applied to every stage of the catapulting process and mass-inertia parameters of helmets taken into account. Kinematic models were used to describe biomechanic parameters of the head-neck system. Special attention was given to the case of catapulting to the air flow. The effect upon the nod of aerodynamic forces acting on the human body and the catapult ejection seat at air flow velocities of 700-800 and 1300 km/h was calculated.

[Text] Analytical description of biomechanics of the human body using kinematic models is simplified [1]. This limits appreciably the range of effective application of such models to situations where internal deformation of the body is not relevant to solution of a concrete problem. On the other hand, expressly this limitation makes the use of kinematic models particularly desirable in cases where the factor to which man is exposed is complicated and estimation of parameters of this factor is not in itself a simple task.

Such situations include emergency exit from a flight vehicle while flying at high speed. In expressly this case, the human body is subject to the combined effect of ejection and air flow accelerations [2, 3].

Let us illustrate the capabilities of kinematic models on the example of calculating the trajectors of head movement in a helmet and evaluation of the possible zones and velocities of impact contact with elements of the seat and cockpit interior as related to different parameters of exposure and mass-inertial characteristics of helmets. To assess the statistical scatter of parameters, we used the results of interpretation of kinograms of head nods in helmet A (arbitrary designation) recorded on a ground-based vertical catapult. We obtained the following regression functions for amplitude (φ_m) and mean angular velocity ($\bar{\varphi}_I$) at the flexion phase:

$$\varphi_{m} = 21,0 + 3,3 n_{max}; \quad r = 0,706 > r_{01} = 0,661;$$

$$\bar{\varphi}_{I} = 0,81 + 0,73 n_{max}; \quad r = 0,796 > r_{01} = 0,661;$$

where n_{max} is maximum acceleration.

Analogous regression equations can be obtained for other parameters of nodding--duration of first phase (τ_I) and total duration (τ), as well as for angle of head turns at different values for dimensionless time $t/\tau = 0.1$, 0.2, etc. "Mean expected nod" as a function of time thus obtained is illustrated in Figure 1 (curve A). In this figure, the dash line shows 95% boundary of confidence interval, i.e., boundaries of the zone in which the angle of turn as a "true function" of time is situated with probability of 0.95. Thus, the most elementary statistical processing enabled us to obtain a significant forecast of kinematics of the head when exposed to impact accelerations of 20 G, i.e., close (in the case of using helmet A) to the maximum permissible value.

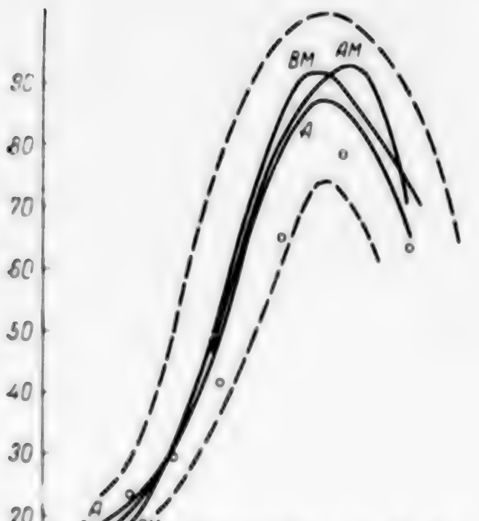

Figure 1.
Angle of turn of head-neck system as a function of time
X-axis, time ($s \cdot 10^{-3}$); y-axis, angle of head turn (degrees)

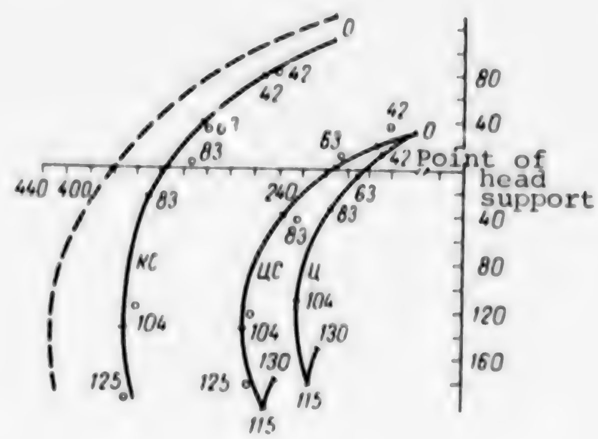

Figure 2.
Trajectory of head and helmet movement while nodding. M 1:2

In Figure 1, curve AM (helmet A--model) illustrates the results of estimating a nod in helmet A with head-pelvis trapezoid impact accelerations of up to 20 G, which is an "idealized" analogue of actual impact accelerations when ejecting [2]. For the calculations, we used the kinematic model of a human body described in [1]. Jugding from the good coincidence of curves A and AM, its applicability for the indicated purpose can be considered warranted, so that we are entitled to use the model to describe nodding in a helmet with somewhat poorer (though similar) inertial characteristics.

It was demonstrated experimentally that the amplitude of a nod, during exposure to pulses of head-pelvis accelerations lasting 0.1-0.2 s at amplitudes of 8-20 G and helmet weight in the range of 0.3-4.5 kg, increases with increase in

amplitude of accelerations or helmet weight, reaching maximum values of 80-100°, which are due to the anatomy of the human body, provided the trunk is firmly immobilized in the seat. In the case of symmetrical (in relation to the sagittal plane of the body) burden, trajectories of points on the head and helmet are also virtually flat curves, while the immediate radius of movement of mass center of the head-helmet system is almost constant and constitutes 0.15-0.20 m. Finally, the dynamics of nodding as a function of time correspond almost exactly to the profile of change in accelerations, and this is quite understandable if we consider that the half-time of autologous oscillations of this system is 1/3-1/4 the duration of accelerations, while extinction in the system is great enough to smooth "high-frequency" superpositions.

It can be expected that these patterns will also prevail in the case of helmet B, the inertial characteristics of which are approximately in the middle of the range discussed. This means that there will be acceleration n_{max} for which $\varphi_B(t)$ (helmet B) function will be similar to $\varphi_A(t)$ (helmet A), if accelerations as dimensionless functions of time $n(t)/20$ for helmet A and $\frac{n(t)}{n_{max}}$ for helmet B are also similar.

In Figure 1, this is illustrated by the coincidence of nominal curves AM (helmet A, 20 G) and BM (helmet B, 18 G). Thus, it can be considered that the mean expected trajectories of nodding for "maximum" burden in helmets A and B are virtually identical (although they are obtained with different levels of accelerations).

Evidently, it would not be a gross mistake to consider that the 95% range of confidence interval of nodding trajectories would also be rather similar, since statistical scatter is determined in both instances by a set of the same random factors (individual anthropometric distinctions, differences in produced position and muscular coordination, effort required to tighten immobilization belts, etc.). In order to additionally check applicability of the adopted system of calculation, the same figure illustrates experimental points obtained in a control experiment (helmet B, 18 G), which are in satisfactory agreement with nominal curves AM, BM and are in the range of the adopted confidence intervals.

The same experimental data are illustrated in Figure 2 along with the mean expected trajectory of the mass center of the head in the helmet (curve Ц, which corresponds to mode A, 20 G or B, 18 G) in coordinates of the ejection seat, correlated to the initial point of head support by headrest. Although the general nature of the estimated trajectory does agree with the experiment, we see that the experimental points are slightly to the left and below the nominal ones for the same points in time (numerals in the figure refer to time after start of nod in milliseconds).

This discrepancy becomes quite comprehensible if we consider that, in the kinematic model, we disregarded internal deformation of the body, i.e., change in form and size of its different segments. In our case, we assumed that the length of the torso remains unchanged and that it is not displaced by virtue of tight immobilization in the seat before ejection. Thus, in our approximation, the immediate center of rotation of the "neck hinge" remains stationary in relation to the seat, whereas trajectory analysis of kinograms of nods shows that with ejection accelerations of ~15 G or more, the nominal shift forward and down of this point reaches tens of millimeters.

Let us add in the nod model displacement of the center of rotation downward, with consideration of longitudinal deformation of the torso calculated on the model described in [4], which reaches 30-35 mm under our conditions. It is obvious that this "foreshortening" of the torso will lead to appearance of slack in the shoulder belt restraining system and, consequently, to additional shifting of the axis of the neck articulation 20-25 mm forward. Maximum forward shift (Δb) can be evaluated with consideration of geometric factors using the following expression:

$$\Delta b \approx (l-\Delta l)\sin\left|\arccos\frac{l^2+L\Delta l}{(l-\Delta l)\sqrt{l^2+(L-l)^2}}-\operatorname{arctg}\frac{L-l}{l}\right|, \qquad (1)$$

where l and Δl are initial length and longitudinal deformation of the torso, in m; L is length of the segment of the restraint belt between points of its attachment, in m.

The trajectory of movement of the mass center, which was calculated with consideration of shift in axis of articulation rotation and is illustrated as curve ЦС in Figure 2, conforms well to experimental functions.

Estimated turns of the head as functions of shifting of the seat during acceleration are illustrated in Figure 3 by curves A (case discussed above) and B (actuation of rocket booster when seat shifts by about 1 m). It is apparent that, in the aspect of concern to us of the possibility of impact contact, the presence of a second acceleration pulse (much lower in amplitude than the first) does not contribute anything that is basically new and does not require additional discussion.

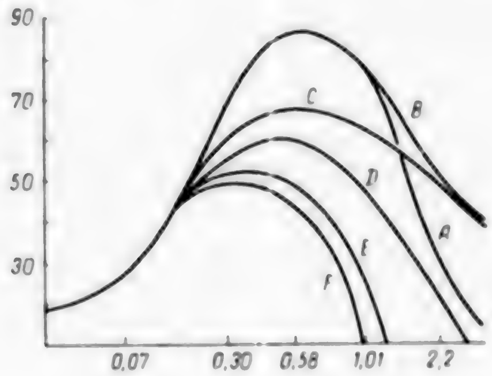

Figure 3.
Effect of rocket booster on kinematics of nodding
X-axis, seat shift (m); y-axis, angle of head turn (degrees)

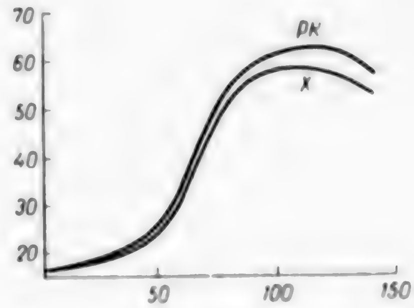

Figure 4.
Angular displacement of head-neck system during inflight ejection
X-axis, time ($s \cdot 10^{-3}$); y-axis, angle of head turn (degrees)

Let us now discuss in the same aspect a more complicated case, namely, the effect on nodding during ejection of aerodynamic forces applied to the human

body and ejection seat at air flow velocity V_i of about 700-800 km/h, which is close to the mean intensity of this factor, and 1300 km/h as the level that is close to the top of the theoretical range of use of open ejection seats [2]. (We are, of course, referring to indicator speeds characterizing the dynamic head of air flow). Aerodynamics of a seat in an air flow have been studied rather well [2]. For this reason, we shall limit ourselves to the assumption that, at the start of the free segment of the trajectory of seat movement, the effect of aerodynamic forces is equivalent in the system of coordinates of the seat to the effect on the human body of additional acceleration n_T in the pelvis-head direction of about 1.5 G at V_i = 700 km/h, 1.7 G at V_i = 800 km/h and 4.4 G at V_i = 1300 km/h. For these velocities, the values for acceleration n_c in back-chest direction constituted 7.0, 8.5 and 25.0 G, respectively.

To describe the kinematics of the head under such conditions, use of a maximally simplified single-element model of a neck articulation in the form of a rigid rod with length R of about 0.17 m, at the end of which point mass (m~7.4 kg) is concentrated, which corresponds to the mass of the head in the helmet, provides satisfactory accuracy. The equation of motion for these conditions will be:

$$\ddot{\varphi} = \frac{mg[n(t) - n_T] - F_\Pi}{mR}\sin\varphi + \frac{mn_c - F_Л}{mR}\cos\varphi - \frac{1}{mR^2}[M_0 + M_1(\varphi - \varphi_0) + M_2\dot{\varphi}], \quad (2)$$

where F_Π is lifting power, in N; $F_Л$ is force of frontal resistance applied to the head, N; M_0, M_1, M_2 are moments of resistance of cervical articulation, M_0 = 1.33 Nm, M_1 = 160 Nm/rad and M_2 = 1.33 (Nm•s)/rad.

It was also assumed that effective head area (S) in the helmet changes as it enters into the zone of action of air flow as a function of displacement of the seat (y_K) in relation to flow and displacement of the head ($y_Г$) in relation to the seat, i.e., :

$$\begin{cases} \Delta y = y_K - y_Г - y_0, \\ y_K = g\int_0^t\!\!\int n(t)\,dt; \\ y_Г = R[1 - \cos\varphi(t)]. \end{cases} \quad (3)$$

where y_0 is initial distance from top point of helmet to zone of action of flow, y_0~0.2 m.

Having assumed, for the sake of simplicity, that the cross section of the head in the helmet is a plane that is perpendicular to flow and that it remains close to circular with head movement with a constant radius r (r~0.13 m), we shall obtain for effective area:

$$
S = \begin{cases} 0; & \Delta y \leq 0; \\ \frac{1}{2}\left[R\,(l - a) + a\Delta y\right]; & 0 < \Delta \leq 2r; \\ \pi r^2; & 2r < \Delta y. \end{cases} \tag{4}
$$

where

$$
\begin{cases} l = 2r \arccos \dfrac{r - \Delta y}{r}; \\ a = 2r \sin \arccos \dfrac{r - \Delta y}{r}. \end{cases} \tag{5}
$$

We can now find the aerodynamic forces (lift and frontal) acting on the head in the helmet:

$$
\begin{cases} F_{\text{П}} = P_{\text{П}}S; \\ F_{\text{Л}} = P_{\text{Л}}S. \end{cases} \tag{6}
$$

Here, $P_{\text{П}}$ and $P_{\text{Л}}$ are coefficients that are related to air density and compressibility, form of streamlined body, its position in flow, etc. To find them, we conducted a series of experiments with a rigid anthropomorphic mannequin in an aerodynamic tunnel. In these experiments, forces $F_{\text{П}}$ and $F_{\text{Л}}$ were measured with tensiometric sensors at different velocities of flow. It was established, in particular, that presence of a small space (up to 30 mm) between the helmet and headrest had virtually no effect on magnitude of aerodynamic forces, while increase in this space due to turn of the mannequin's head up to φ~60° led to slight (10-20%) increase in these forces. Since this increase could only lead to limitation of nodding amplitude and velocity, it was assumed that $P_{\text{П}}$ and $P_{\text{Л}}$ are independent of φ.

Aerodynamic coefficients of the head in helmet under different flying conditions

Nominal case	Coefficient $P_{\text{П}}$, kPa	Coeff. $P_{\text{Л}}$, kPa	Velocity V, km/h	Flying altitude, km
λ	10,9	14,2	700	4
C	12,1	14,1	800	0
D	14,9	24,9	800	11
E	37,5	58,7	1300	0
F	35,[illegible]	77,5	1300	11

The averaged values of these coefficients for different nominal cases are listed in the table.

The angle of turn φ as a function of seat displacement for hominal cases C, D, E, F are illustrated in Figure 3. We can see well that an increase in aerodynamic forces applied to the head in the helmet leads to dramatic decrease in amplitude of nodding (with concurrent decline of its maximum and mean velocity at least in the phase of moving forward and down). This means that there is reduction of the zone of possible impact contact and, apparently, from this point of view, presence of air flow in any case does not lead to additional adverse consequences at the first phase of a nod.

We can also see well that forces preventing development of a nod at its second phase--opposite head movement--lead to increase in angular and, consequently, linear velocity of its approach to the seat headrest up to about 6.0 m/s.

Let us also mention that, in spite of the assumptions made in constructing the calculation model of nodding, in particular, in describing aerodynamics, the results obtained with this model are in satisfactory agreement with the existing experimental data (although true, they are quite limited). Figure 4 illustrates the results of interpreting kinograms of nods (curve PK) recorded during inflight ejection in a mode close to our nominal case X (see Table). We see that the model of a nod, which considers inertial characteristics of helmet C (curve X) provides a rather satisfactory description of kinematics of the head in this helmet in both general features and depth of nodding.

Thus, use of kinematic models to describe movements in the head-neck system at all stages of the ejection process in a flow of air yields satisfactory results. However, for fuller comprehension of the biomechanics of nodding during ejection, one must use more detailed, multi-component dynamic models that take into consideration not only the external parameters of nods, but internal deformation of the body, primarily elements of the spine.

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METHODS

UDC: 615.472.03:612.76.014.47-064

METHOD OF ENHANCING INTERFERENCE RESISTANCE OF OPERATOR PERFORMANCE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (Manuscript received 16 Jul 86) pp 78-79

[Article by Ye. T. Petrenko and L. A. Yermukhametova]

[Text] Some types of professional motor activity of man are performed under extreme conditions in the presence of exogenous interference. Efficiency of performance in such cases is largely determined by the degree of interference resistance of the control system, in particular its higher branches, the cerebral cortex.

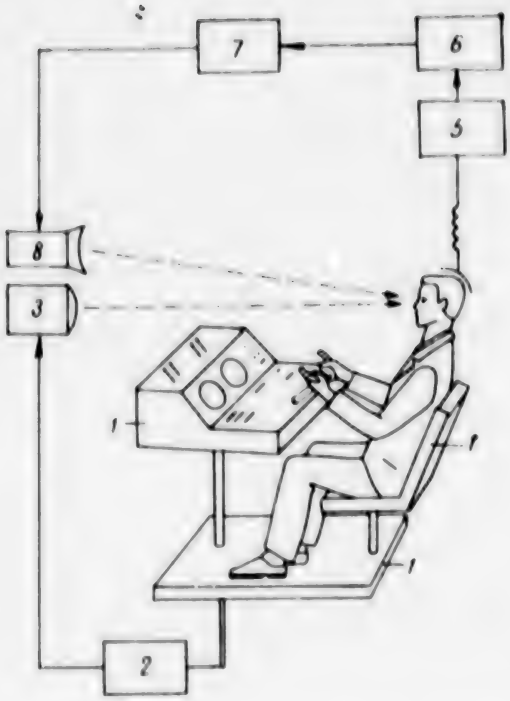
The results of investigations have shown that the ability to assimilate the rhythm of light flashes in the range of 10-12 Hz, as well as rhythm of the basic individual oscillation frequency of electrical activity of the brain during motor activity, are related to the extent of resistance of movements to photic stimulation [1-5]. Various individual levels of central nervous system and movement resistance to rhythmic photic interference were demonstrated.

On the basis of the studies, a method was developed to improve man's efficiency [5], which is intended to condition motor resistance to interference, as well as a device, Alpha-rhythm 2, to implement the method.

The purpose of this development was to enhance professional work capacity of operators in the presence of exogenous interference by means of exposing them to rhythmic photic and acoustic signals.

The method is based on the effect on man in the course of professional motor activity of photic and acoustic signals in the rhythm of the basic frequency of his electroencephalogram. The portable Alpha-rhythm 2 unit consists of a miniature amplifier and analyzer of cerebral bioelectric potentials with exploring electrodes on the helmet, a unit to form control pulses, units of formation of photic and acoustic pulses, unit of sensors of biomechanical characteristics of motion and an oscilloscope.

Training is performed in the following manner (see Figure). The subject is seated at his work place *1*, which contains devices that simulate control of an aircraft connected to sensors of biomechanical characteristics of movements *2*, which are linked with the unit for visual display *3* and carry information about the nature of his movements, which is expressed in newtons, joules,



Block diagram of training conditions; explained in the text

seconds, coordinates, etc. Using electrodes *4*, bioelectric potentials are derived from motor regions of the cerebral cortex, which are directed to amplification unit *5* and from there to analyzer *6*, where the intrinsic frequency of dominant rhythm of electrical activity of cerebral regions involved in processes of controlling movement is isolated. After finding the individual dominant frequency (for example, 9 Hz), its analogue is directed to the unit for formation of stimulating pulses *7*, and from there to the unit that generates photic and acoustic pulses *8* proportionately to the level of interference inherent in pilot work, in the rhythm of the isolated frequency of electrical activity of the brain. For example, the level of intermittent sound is 90 dB, which corresponds to engine noise, while the magnitude of flashes of 30,000 lux corresponds to solar illumination.

Artificial interference lowers the pilot's work capacity, as manifested by increased exertion applied to the control wheel, deviation of target on the screen, longer choice reaction, increased number of erroneous choices, increased expenditure of energy, etc. As he observes on the unit of visual display *3* the decrease in efficiency of movements, the operator makes voluntary efforts to correct his actions in accordance with the standard requirements of the motor program.

The entire course of training takes 15-20 days (4-5 times a week; 35 min each time). The training conditions correspond to future working conditions.

As a result of this training, an interference-resistant system is formed to control movements, which is manifested by the individual's ability to maintain a high mechanical effect of motion in the presence of various types of interference for a long period of time. As shown by a test of this method in an industry analogous to the professional activities of operators, the effect of a single training course persists for 6 to 8 months (depending on individual capabilities). In this regard, 2 training courses per year at 6-month intervals are sufficient to main a high level of professional work capacity.

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UDC: 629.78:612.172.4.014.421.7

AUTOMATED ANALYSIS OF VECTORCARDIOGRAMS IN SPACE MEDICINE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 28 Feb 86) pp 79-82

[Article by N. I. Vikhrov, L. S. Solovyeva, V. D. Turbasov, V. K. Vasilyev, B. R. S. Reddi and R. S. Chattarjee (USSR and Republic of India)]

[Text] There are some advantages to the use of vectorcardiographic leads for examination of bioelectrical activity of the heart from the standpoint of automation, as compared to the 12 conventional electrocardiogram (ECG) leads, since it reduces to one-fourth the volume of data recorded and inputted in computers. For this reason, vectorcardiography methods are gaining increasing use in medical support of spaceflights. Cardiac function of crew members aboard the Skylab orbital station was examined using vectorcardiograms (VCG) recorded in modified orthogonal leads of Frank in the course of medical experiments involving lower body negative pressure and exercise on a cycle ergometer.

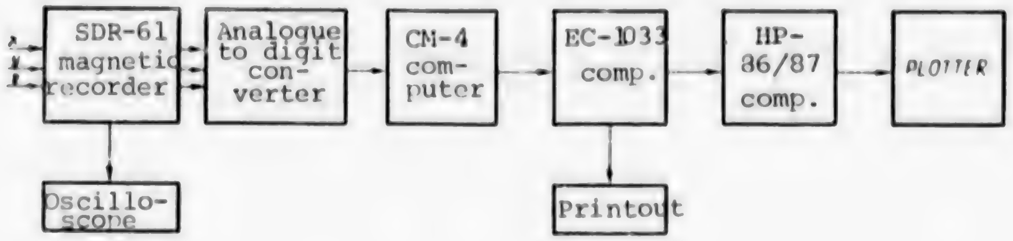
We discuss here the system of automated processing of vectorcardiographic data which was developed jointly by Indian and Soviet specialists for analysis on a computer of VCG obtained while preparing for, during and after the Soviet-Indian mission to the Salyut-7 station by cosmonauts Yu. V. Malyshev, G. M. Strekalov and R. Sharma.

Methods

We examined the spatial characteristics of the heart's electric field, from VCG recorded in Frank's orthogonal leads [3] on the cosmonauts, on the ground and in weightlessness at rest (5 min), during exercise (power of 130 W, 5 min) on a cycle ergometer and in the recovery period (5 min). VCG were recorded using a special onboard vectorcardiograph, and analogue signals were recorded (with frequency modulation) on a 4-channel portable SDR-61 magnetic recorder. Electrocardiographic signals from leads X, Y, Z were recorded on the first 3 tracks, and baseline data and comments in the course of the test were recorded on the 4th (audio) track. At first, we recorded calibration signals for each of the three leads. The calibration signals were square-wave pulses recurring at a frequency of 2 Hz and amplitude of 1 mV, with 2-s calibration time.

A 3-channel digital-to-analogue converter, which provided for conversion at the rate of 500 measurements per second on each channel, was used to digitize the analogue electrocardiographic signals recorded on the magnetic recorder and

input them in the CM-4*computer. At the output of the converter, each ordinate was submitted in a 10-bit binary code. At first, the calibration signals were digitized and recorded on magnetic tape in a file of the CM-4 computer, then the VCG signals at rest, during exercise and in the recovery period. The digitized data were processed on a EC-1033*computer using the VECTOR program, which was developed in the FORTRAN-IV language. The basic part of the program for retrieval and processing of QRS complexes was developed by B. R. S. Reddi. Before processing, the digitized data were viewed on a graphic display in order to select appropriate segments of the baseline, exercise and recovery periods for automated processing. The program provided for automatic processing of 10-s VCG runs. At first, we processed the calibration signal, after which the data were converted to microvolts in the computer and thereafter all amplitude measurements were made in microvolts and times in seconds. The VECTOR program detects each cardiac cycle and measures its main parameters of amplitude and duration of waves; it also reproduces mathematical elements of spatial vector loops of P-QRS-T complexes and several other quantitative parameters.



In processing, first of all the QRS complexes are retrieved and measured; for this purpose, baseline data are smoothed by means of averaging at three points and calculation of spatial velocity moment-to-moment:

$$SV = (\Delta X)^2 + (\Delta Y)^2 + (\Delta Z)^2$$

where $\Delta U = U(i) - U(i - 1)$, $U = X, Y, Z$. After this, we find the VCG points in which SV is greater than the specified threshold determined in advance according to maximum absolute value of the derivative at the point on the posterior front of the R wave. The distance between two adjacent VCG points, in which SV assumes a greater than given threshold value, determines the duration of RR interval. The begining and end of each spatial WRS complex are found as points at which SV is below the given thresholds in relation to the isoline.

Thus, on the basis of analysis of spatial velocity, we found QRS complexes, their duration and duration of RR intervals for the processed VCG segment. After this, averaged QRS complexes were formed for each of the three leads (X, Y, Z) by adding the corresponding ordinates by superposing the start of

*Translator's note: Source does not specify whether Cyrillic or Latin letters were used in designating computer models; CM could be SM [Cyrillic], EC may be YeS, HP could be NR. In this article, the first (Latin] version is used, since magnetic recorder model is rendered unquestionably in Latin letters.

all QRS complexes. In averaged QRS complexes, the program was used to measure, every 0.004 s, the ordinates of vector loop projections in three mutually perpendicularly planes: frontal (X, Y), horizontal (X, Z) and sagittal (Y, Z). Retrieval and isolation of boundaries of R and T waves were also effected by calculating the spatial velocity SV in corresponding regions to the left and right of the QRS complex with use of threshold logic for detection of waves and determination of their limits. Analogously, averaged P and T waves were found for each of the three (X, Y, Z) leads, and measurement made of ordinates of their projections on planes XY, XZ and YZ. The vector loops were rendered graphically in a rectangular system of coordinates with consideration of polarity of recorded leads using an HP-86/87 microcomputer.

The above-described automated system was used for computer processing of all VCG recorded on cosmonauts in the preflight, inflight and postflight periods at rest and during exercise. At rest (before and after pedaling), the program found and processed P, T and QRS complexes. During pedaling, in view of the presence of significant interference in the signals due to muscular activity, it was possible to detect and process only QRS complexes on the VECTOR program.

The program determined coordinates X, Y, Z of vector loops P-QRS-T, angles of orientation of projections of instantaneous vector in the frontal, horizontal and sagittal planes, angle of elevation of instantaneous spatial vector, voltage of instantaneous vector and moment spatial vector, maximum vector velocity, area of spatial vector loop and a few other parameters [1].

Results and Discussion

Typical dynamics of VCG parameters were observed in all cosmonauts before and after flight under the effect of exercise: decrease of maximum vectors and loop area during and immediately after exercise (see Table) and return of parameters to baseline values by the end of the recovery period. There were no anomalous changes in VCG morphology.

During the flight, at rest and during exercise, maximum vectors and area of QRS complex loops increased significantly in Yu. V. Malyshev. The most likely cause of this phenomenon is redistribution of blood in a cranial direction, which elicits the Brody effect [2]. Such changes are expected in the course of short-term spaceflights.

On the whole, the changes in vectorcardiographic parameters under the influence of spaceflight factors were moderate. After the flight, the parameters reverted to the preflight range within 4 days.

Spaceflights of such duration do not have an appreciable effect on the functional state of the cardiovascular system or on bioelectrical activity of the heart of conditioned people.

Thus, testing of this developed system of automated VCG analysis during spaceflights revealed that it is highly effective and that it is desirable to use it in the future in space medicine.

Dynamics of some parameters of QRS complex VCG of Yu. V. Malyshev before flight at rest

Parameter	Time, s								
	0.00	0.01	0.02	0.03	0.04	0'05	0.06	0.07	0.08
At rest									
QRS voltage, μV:									
X	2	—10	—65	175	687	1020	564	7	19
Y	1	—3	81	189	680	978	318	—12	—54
Z	1	—48	—173	—578	51	564	434	288	32
Moment vector voltage, μV:									
Hz	2,2	49,0	134,8	416,5	688,9	1163,5	711,7	288,1	37,2
Fr	2,2	10,4	103,9	257,6	966,6	1413,1	647,5	13,9	57,2
LS	1,4	48,1	191,0	422,6	681,0	1129,0	538,0	288,2	62,8
Orientation of moment vector, degrees:									
Hz	26,6	—101,8	—110,6	—65,2	4,2	28,9	37,6	88,5	59,3
Fr	26,6	—163,3	128,8	47,2	44,7	43,8	29,4	—59,7	—70,6
LS	45,0	—176,4	154,9	153,4	85,7	60,0	36,2	—2,4	—59,4
Voltage of spatial moment vector, μV	2,4	49,1	201,8	457,4	968,0	1521,5	779,5	288,3	65,6
Elevation of spatial moment vector, degrees	24,1	—3,5	23,7	24,4	44,6	40,0	24,1	—2,4	—55,4
Maximum vector velocity (spatial vector), degrees	126,2	28,5	41,3	58,8	18,8	17,5	56,2	58,1	—
In first minute after exercise									
QRS voltage, μV:									
X	1	—8	—67	701	506	796	307	—35	—70
Y	—7	5	85	182	647	349	218	—66	—133
Z	—3	—34	—121	—263	120	633	476	277	52
Moment vector voltage, μV:									
Hz	3,2	34,9	138,3	281,7	520,0	1017,0	565,6	292,8	87,2
Fr	7,1	9,4	108,2	208,1	821,4	1163,8	382,4	115,7	150,3
LS	7,6	34,4	147,9	319,8	658,0	1059,0	526,9	284,8	142,8
Orientation of moment vector, degrees:									
Hz	—71,6	—103,2	—119,0	—69,0	13,3	38,5	57,1	108,9	143,4
Fr	—81,9	148,0	128,3	61,0	52,0	46,8	36,6	—145,2	—117,8
LS	—113,2	171,6	144,9	145,3	79,5	53,3	25,6	—13,4	—68,7
Voltage of spatial moment vector, μV	7,7	35,3	162,3	335,4	830,1	1324,8	609,8	300,2	159,0
Elevation of spatial moment vector, degr.	—65,7	8,1	31,6	32,9	51,2	39,9	22,0	—12,7	—56,8
Maximum vector velocity (spatial vector), degrees	77,5	27,6	41,9	60,5	20,8	23,9	61,5	51,3	—

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BRIEF REPORTS

UDC: 612.766.1-06:612.886

EFFECT OF VESTIBULAR STIMULATION ON STATIC PHYSICAL WORK CAPACITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 10 Jul 86) pp 83-84

[Article by A. A. Podshivalov]

[Text] It was previously shown that there is a close link between the muscular and vestibular systems [1, 3, 4, 7-9, 12]. In particular, the opinion has been voiced that change in interaction of sensory systems, as well as removal of static load on muscles in weightlessness, could alter the activity of antigravity muscles [6]. At the same time, the effect of stimulation of the human vestibular system on functional state of different groups of extensor muscles that have antigravity functions has not been investigated sufficiently. It is of particular interest to study the static physical work capacity (SPW) of cervical extensors, since we know that there is a close correlation between tonic neck and labyrinthine reflexes [5, 8, 14].

Methods

A total of 24 subjects 19-40 years of age participated in these studies. We used the test of S. S. Markaryan [9] as a vestibular stimulus. Vestibular stimulation was delivered until there was development of manifestations of moderate motion sickness. The method of R. R. Galle [2] was used to evaluate the vestibulovegetative reactions.

The static muscular load test (SMLT) was performed in 30 studies of extensors of the legs and 22 with extensors of the neck. There were 10 control studies. In each study, SMLT was performed twice, before and after motion sickness, and in control studies without stimulation of the vestibular system at 5-min intervals. In the SMLT, the method described in [3], which was modified to take into consideration the distinctions of testing SPW of neck extensors on a vestibulometric stand, served as the basis. The device for recording isometric muscular contractions consisted of an air-filled rubber cuff with a strain gage that recorded the magnitude and duration of force applied to the cuff. The cuff was connected to a mercury manometer, with which magnitude and stability of applied effort were monitored. For SMLT of leg extensors, the cuff was placed on a footrest, and for testing cervical extensors, on the headrest of the vestibulometric stand.

The SMLT consisted of six gradually increasing isometric muscular contractions, each being held for 30 s. These efforts constituted $5.3 \cdot 10^2$ to $7.9 \cdot 10^2$ N for extensors of the legs, and the static work performed defined as a power impulse ranged from $15.9 \cdot 10^3$ to $23.7 \cdot 10^3$ N•s, while maximum total work constituted 119.7 10 N s. When using the SMLT for extensors of the neck, the applied isometric contractions ranged from $1.9 \cdot 10^2$ to $3.2 \cdot 10^2$ N, static work ranged from $5.7 \cdot 10^3$ to $9.6 \cdot 10^3$ N•s, and total work constituted $45.5 \cdot 10^3$ N•s. End exertion constituted about 75% of the maximum for this group of subjects. When a subject achieved well in the SMLT with exertion of 75% of the maximum, he was asked to generate a maximum effort and maintain it for the maximum possible time. Decline of maintained static muscular exertion by 25 N in relation to the required level, or the subject's refusal to continue the test served as the criterion to stop the test.

Subsequently, 9 subjects underwent a 5-day cycle of passive vestibular conditioning (for up to 30 min daily) with graded, contrived displacement of the head by an angle of ±30° in the sagittal plane and concurrent rotation at angular velocity of 120°/s. SPW of cervical muscles was tested before the 5-day training cycle and after it, and extent of decline of SPW was tested after stimulation of the vestibular system following one and five conditioning sessions.

An RM-150 Polygraph was used to record during the studies the magnitude and duration of static muscular contractions, ECG, tachooscillogram, minute volume of respiration (MV), respiration rate (RR). Physiological parameters were recorded for 3 min before SMLT, every minute during SMLT and 3 min after the test. Statistical significance of results was determined using Student's parametric criterion (p_t) and the nonparameteric criterion of Vald-Volfovits (p_n). We calculated extensive parameters of increment in MV, RR, heart rate (HR) and arterial pressure (BP) in relation to baseline values. Baselines were determined as the means of three measurements before SMLT.

Results and Discussion

SPW declined after vestibular stimulation (endurance time 3.28±0.3 min) in the presence of development of symptoms of motion sickness (score of 5.68±0.47). Static function of leg extensors decreased from $108.35 \cdot 10^3 \pm 3.32 \cdot 10^3$ to $99.82 \cdot 10^3 \pm 4.28 \cdot 10^3$ N•s ($p_t > 0.05$), and that of cervical extensors from $45.7 \cdot 10^3 \pm 0.57 \cdot 10^3$ to $41.5 \cdot 10^3 \pm 0.48 \cdot 10^3$ N•s ($p_t < 0.05$). In the control tests without vestibular stimulation, not only did we fail to demonstrate a decline but (in 2 cases in a repeated SMLT) even some increase.

HR, BP, MV and RR after the vestibular test changed in different directions, so that no statistically significant differences between their pre- and post-test values were demonstrated. We also failed to demonstrate an appreciable difference in changes in these parameters during SMLT on different groups of extensors. In both groups of subjects, by the 3d min of the test, HR increased during the SMLT by 45-60% before motion sickness and by 30-60% of the baseline after, which is in agreement with data obtained with isometric contraction of neck muscles [13]. The parameters of maximum lateral and mean hemodynamic pressure rose by 30-40%, and minimal by 5-15%, both before and after the vestibular test. MV increased by 50-90% before the vestibular test and 60-120%

after it, RR increased by only 20-50% before the vestibular test and 15-20% after motion sickness. It can be assumed that the post-test increase in MV occurrs due to increase in respiratory volume. Perhaps, this is related to the onset of respiratory arrhythmia in many subjects during the SMLT after the vestibular test (p_n<0.5). Respiratory and circulatory parameters reverted to the baseline 2-3 min after the SMLT. Subjects in all groups showed a drop of minimal BP, by 5-10% of the baseline, in the first 1-2 min after SMLT, performed both before and after the vestibular test.

During the SMLT after the vestibular test, 70% of the subjects reported disappearance of counter-rotation illusion, which is indicative of the possibility of using contraction of extensors to suppress illusion responses during spaceflights [11].

After the training cycle, the absolute SPW increased by 1.5-2 times, there was less decline of SPW after stimulation of the vestibular system. Thus, while SPW of cervical muscles after vestibular stimulation constituted 70.5±7.4% of the baseline during the first training session, it was 99.5±8.8% after the 5th.

Thus, the results revealed that SPW diminishes after stimulation of the vestibular system and development of autonomic motion sickness reactions. The reliable decline of SPW of cervical extensors with vestibular stimulation confirms the close connection between proprioceptors of cervical muscles and the vestibular system. Passive vestibular conditioning with prolonged, contrived displacement of the head enhances SPW of cervical muscles and prevents its decline following vestibular stimulation.

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CHANGES IN RAT HEMOPOIESIS AS A RESULT OF THE COMBINED EFFECT OF ACCELERATIONS, RADIATION AND RADIATION-MODIFYING AGENTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 22 Jan 86) pp 85-86

[Article by V. B. Tenchova and T. P. Pantev (People's Republic of Bulgaria)]

[Text] Spaceflight factors (SFF) lead to a number of changes in hemopoiesis, the severity of which depends on the nature, duration and order of exposure to such factors. Accelerations, weightlessness, vibration and certain other factors can modify not only radiation lesions, but pharmacotoxic and protective properties of radioprotective agents and substances for biological protection.

Cellularity of bone marrow and the spleen is one of the indicators of the radiation=protective effect of chemical agents and substances that enhance natural resistance.

Our objective here was to investigate changes in overall cellularity of bone marrow, weight and cellularity of the spleen of rats submitted to the combination of accelerations and radiation, as well as the possibility of modifying these changes with eleuterococcus and the radioprotective agent adeturon.

Methods

Experiments were performed on male Wistar rats which were divided into 7 groups, 6 experimental and 1 control, with 10 animals per group, depending on the types of factors used: radiation, accelerations, eleuterococcus + radiation, eleuterococcus + accelerations + radiation, eleuterococcus + accelerations + adeturon + radiation. For 14 days, the animals were given water containing eleuterococcus extract at the rate of 5 mℓ/kg. The daily dose was given once on the 7th and 14th days. On the 14th day, 1 h before irradiation, the animals were submitted to accelerations (+5 Gx) for 5 min on a Janetzki S-50 centrifuge with a 20.5 cm arm. Radiation was delivered in the form of ^{137}Cs γ-rays from an IGUR-1 source in a dosage of 3 Gy at a dose rate of 1.015. Adeturon was given intraperitoneally in a dosage of 300 mg/kg 15 min before irradiation. Rats were sacrificed under ether anesthesia, then determination was made of overall cellularity of bone marrow in one femur, weight, total and specific cellularity of the spleen [1, 2]. The above parameters were determined on the 3d and 10th postexposure days.

Results and Discussion

Data pertaining to changes in total number of nuclear bone marrow cells in experimental animals are listed in the table. Radiation in a dosage of 3 Gy led to decrease in overall cellularity of marrow on the 3d day after irradiation (47% of normal). On the 10th day, we observed an increase in number of karyocytes, although it did not reach normal levels. Administration of eleuterococcus before irradiation increased the number of bone marrow cells. With use of eleuterococcus and the protective agent, adeturon, there was normalization of the tested parameters both in the period of maximum depletion of the cell pool and in the recovery period. With exposure to accelerations, no statistically reliable changes were demonstrable at the tested times, with the exception of decrease in myelokaryocytes on thd 3d day after exposure.

Overall cellularity of bone marrow, weight and cellularity of rat spleen ($\overline{X}\pm SE$) (% of control)

Parameter	Factor	Exposure day	
		3	10
Bone marrow cellularity, $\cdot 10^6$	О	47.6 ± 2.8*	69.4 ± 3.6*
	У	84.9 ± 5.6*	89.6 ± 4.8
	Э+О	70.2 ± 4.3*	71.6 ± 9.5*
	Э+А+О	108.9 ± 4.8	110.8 ± 3.7
	Э+У+О	27.6 ± 0.8*	65.6 ± 1.7*
	А+У+А+О	73.8 ± 2.8*	86.3 ± 7.7
Spleen weight, mg	О	72.8 ± 7.2*	78.9 ± 5.9*
	У	104.1 ± 1.5	86.3 ± 4.7
	Э+О	86.9 ± 1.1*	78.4 ± 1.9*
	Э+А+О	90.6 ± 4.7	84.9 ± 4.9
	Э+У+О	37.8 ± 2.2*	41.6 ± 0.8*
	Э+У+А+О	34.9 ± 1.1*	59.4 ± 1.7*
Spleen cellularity, $\cdot 10^6$, overall	О	42.7 ± 1.5*	58.4 ± 5.8*
	У	100.4 ± 6.9	114.9 ± 7.7
	Э+О	48.3 ± 4.8*	82.9 ± 6.2
	Э+А+О	84.0 ± 5.4	113.4 ± 9.4
	Э+У+О	26.6 ± 1.2*	41.2 ± 3.1*
	Э+У+А+О	50.8 ± 5.5*	58.6 ± 2.6*
Specific cellularity of spleen, $\cdot 10^6$/mg	О	30.5 ± 1.8*	65.3 ± 6.3*
	У	78.6 ± 7.9	121.2 ± 8.5
	Э+О	61.4 ± 2.2*	94.7 ± 3.1
	Э+А+О	71.4 ± 13.3	117.7 ± 2.2
	Э+У+О	15.4 ± 2.1*	87.8 ± 4.4
	Э+У+А+О	125.5 ± 13.4	105.5 ± 3.3

*$P<0.05$

Key: О) irradiation
У) accelerations
Э) eleuterococcus
А) adeturon

In animals given eleuterococcus and submitted to accelerations and irradiation, there was a decrease in overall cellularity of bone marrow, and it was particularly marked on the 3d day after exposure. Administration of adeturon elicited an increase in cell content of bone marrow at both tested times. Other parameters characterizing hemopoiesis (weight and cellularity of the spleen) changed analogously to cellularity of bone marrow with administration of eleuterococcus. Exposure to accelerations combined with irradiation worsened these parameters, as compared to irradiation alone. Lowest weight and cellularity of the spleen were recorded in animals exposed to accelerations and radiation. Additional administration of radioprotective agent between exposure to accelerations and radiation following eleuterococcus had a beneficial effect on these parameters.

The quantitative changes in cellularity of bone marrow, weight, total and specific cellularity of the spleen indicate that marked changes in severity and duration of depressed hemopoiesis, regardless of use of eleuterococcus, are demonstrable first in the group of animals exposed to the cobmination of accelerations and radiation. When there is a relatively short interval between these factors (1 h), acceleration enhances the radiation effect. Moreover, the combination of acceleration and irradiation modifies the effects of eleuterococcus and adeturon. While normalization of all parameters was observed in animals exposed to radiation alone, under the effect of the combined use of eleuterococcus

and adeturon, with use of accelerations and radiation the effect was less marked and attributable mainly to the radioprotective agent.

Our findings indicate that reactivity to both radiation and radiation-modifying agents changes under the combined effect of exposure to accelerations and radiation.

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EFFECT OF VOLUNTARY CONTROL OF RESPIRATION ON FUNCTIONAL STATE OF THE CARDIORESPIRATORY SYSTEM IN THE PRESENCE OF HYPOXIC HYPOXIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 14 May 86) pp 86-87

[Article by Ye. P. Gora]

[Text] At the present time there are no clearcut ideas about the effect of modification of voluntary breathing on functional state of the body in the presence of acute hypoxia [1, 3-5]. Our objective here was to test the influence of some modes of voluntary respiration on cardiorespiratory system function in the presence of different degrees of acute hypoxic hypoxia.

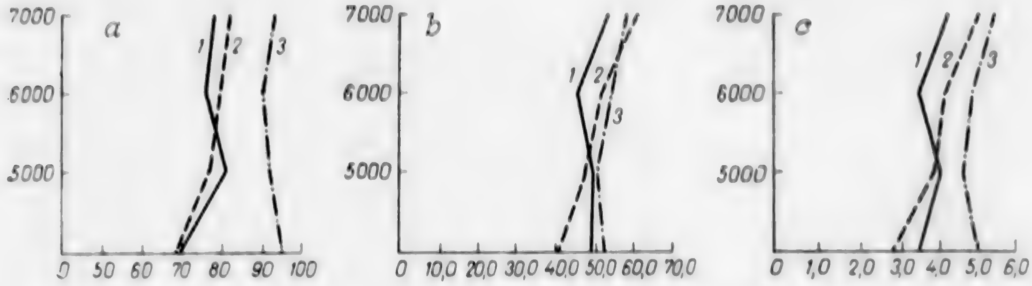
Methods

The study was conducted with the participation of 11 essentially healthy men 29-48 years of age. The subjects held their breath in inspiration and effected ungraded voluntary 2-min hyperventilation on the "ground" and during "ascents" in a pressure chamber to "altitudes" of 5000, 6000 and 7000 m. We recorded their parameters of external respiration, gas exchange (with the exception of breath-holding), ECG in the second standard lead, and arterial pressure with the subjects breathing calmly and during the breathing tests. We calculated stroke (SV) and minute (MV) volume of the heart [2].

Results and Discussion

During tests on the "ground," breath holding for a mean of 49±6.3 s was associated with insignificant decrease in heart rate (HR: $p>0.05$). Systolic arterial pressure (BPs) rose by 4.1%, diastolic (BPd) by 12.5%. Pulse pressure (BPp) decreased by 12.5%. Changes in other hemodynamic parameters are illustrated in the figure, in *b* and *c*.

During elevation in the chamber, breath-holding time decreased to 20±3.2 s at an altitude of 5000 m and to 16±2.8 s at 7000 m. However, while this led to a 4.9% decrease in HR at 5000 m, it caused increase of this parameter by 3.9 and 5.1% at altitudes of 6000 and 7000 m, respectively (see Figure, *a*). BPs increased by 5.8% at 5000 m and by 11.3% at 7000 m. BPd increased by 6.2% at an altitude of 5000 m. Thereafter, no reliable changes in this parameter were demonstrable. BPp increased progressively from 5% at 5000 m to 35% at 7000 m. The dynamics of SV and MV are illustrated in the figure, *b* and *c*.



Dynamics of HR (*a*; per min), SV (*b*; in mℓ) and MV (*c*; ℓ/min) under normal conditions and during ascent in pressure chamber to altitude of 7000 m during calm breathing and in different modes of voluntary control of breathing

X-axis, "altitude" (m): 1) calm breathing
2) breath-holding
3) hyperventilation

Y-axis: a) HR, b) SV, c) MV

Under normal conditions, the changes in the respiratory system during hyperventilation were associated with 35.7% increase in HR. BPs and BPd dropped by 5.7 and 7.3%, respectively. No reliable changes in BPp were noted.

In the presence of altitude hypoxia, the changes in external respiration and gas exchange during voluntary hyperventilation were associated with circulatory system changes. BPs and BPp presented the same dynamics as on the ground at an "altitude" of 5000 m; reverse dynamics were noted at 6000 and 7000 m. BPd progressively declined.

The results of this study indicate that breath-holding at 6000 and 7000 m, in spite of the decrease in its duration, generaly had the opposite effect on the cardiovascular system, as compared to the effect under norm conditions and at 5000 m.

During voluntary hyperventilation, as the hypoxic effect increased there was increase in absolute CO_2 ($\dot{V}CO_2$) output, while O_2 ($\dot{V}O_2$) uptake decreased. The dynamics of functional parameters of the cardiovascular system under normal conditions and at high "altitudes" presented a similar tendency under the influence of this breathing test.

Thus, voluntary breath-holding and hyperventilation have effects in different directions on the cardiovascular system on the "ground" and at altitudes of up to 5000 m. Starting at an "altitude" of 6000 m, these different modifications of voluntary breathing led to increase in strain on the cardiovascular system. This was particularly distinct during hyperventiation. An altitude of 6000 m is, so to speak, the threshold for this physiological function. This apparently can be attributed to the substantial intensification of cardiovascular system function, due to the metabolic oxygen requirements of the body at high altitudes.

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EFFECT OF COOLING AND FREEZING ON MICROFLORA IN WATER REGENERATED FROM ATMOSPHERIC MOISTURE CONDENSATE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (manuscript received 29 Oct 85) pp 87-89

[Article by M. I. Shikina, S. V. Chizhov and N. B. Kolesina]

[Text] Much importance is presently attributed to the problem of supplying man with regenerated drinking water under different conditions [4]. It has been suggested that water be recycled from a number of types of moisture-containing waste, for example, from atmospheric moisture condensate by the sorption method. It has been shown that in a sealed environment, the condensate of atmospheric moisture and water at different stages of regeneration differ from naturally occurring potable water in that they have specific distinctions of bacterial and physicochemical composition [2, 3, 5]. It is interesting to further investigate the survival of microorganisms in such products under the effect of various physical and chemical factors, including low temperatures. It is known that long-term cooling and, particular, freezing lead to depression of vital functions of microorganisms. However, these factors could elicit merely temporary arrest of reproduction of microorganisms (microbostasis) followed by reactivation, rather than destruction of these microorganisms. Some authors report that there is stimulation of growth of microorganisms in foodstuffs under certain conditions, after freezing and subsequent defrosting [1].

Our objective here was to test the effect of low temperature on growth and development of microflora in a condensate of atmospheric moisutre and regenerated water.

Methods

We tested samples of actual atmospheric moisture condensate and regenerated water taken during operation of a water-supply system in a closed environment, in the presence of man, as well as aqueous suspensions of pure cultures of microorganisms isolated from these media. In addition, we conducted studies on a bacterial simulator prepared by means of artificial infection of sterile dechlorinated tap water with cultures of microorganisms.

We used cultures isolated from water-supply systems as test objects: Gram-positive coccal microflora (Staphylococcus epidermitis, Streptococcus faecalis),

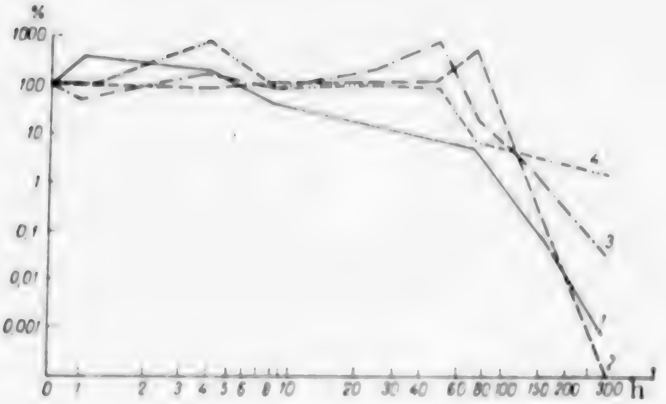
oxidase-positive Gram-negative bacteria (Aeromonas hydrophylla, Alcaligenes faecalis, Citrobacter freundii). For comparison, we concurrently used stock cultures of E. coli strain 675, with which such studies are conducted the most often. The level of initial contamination of the samples constituted 10^5 microbial bodies per milliliter. The water was infected by means of flushing cells with water from the surface of day-old cultures. In order to obtain the desired concentration of microorganisms in the water, washings from slant cultures were diluted to 2.5-3.0 optical density determined with an FEK-M-57, with use of tray No 5, and we added specific volumes of the obtained suspension to the water. A special selection established that in order to obtain a bacterial burden in water on the order of $(4-7)\cdot10^5$ microbial bodies/mℓ in a container with 2 ℓ water, it is necessary to add 1.0-1.5 mℓ of each suspension using a sterile, graduated pipette. To obtain other burden levels, we made the appropriate conversions. The culture suspension was decanted in sterile test tubes, 10 mℓ in each, and one batch was refrigerated at +5 to +6°C, another at -10 to -12°C. The contents remained liquid at the former temperature and froze at the latter. Control test tubes were kept at room temperature. At certain intervals, the test tubes were removed from the refrigerator, the frozen suspension was allowed to thaw and inoculated, after which the tubes were not returned to the refrigerator and were not used for subsequent plating. Subsequent inoculations were made using material from fresh tubes taken from the refrigerator. The samples were inoculated by the surface method in Petri dishes with beef-extract agar, at the rate of 0.1 mℓ per dish without dilution and in 1:10 and 1:100 dilutions. Colonies were counted after the dishes were incubated for 24 h at 37°C.

We also investigated viability of microorganisms in samples of atmospheric moisture condensate and regenerated water stored for a long time (up to 1 year) in sterile tubes with cotton-gauze stoppers at room temperature (18-20°C), in an incubator at 37°C and refrigerator at temperatures of -10 to +5°C.

Results and Discussion

The study of viability of different species of microorganisms in aqueous suspensions with baseline microbial burden of 10^4-10^5 microbial bodies/mℓ revealed that the rate of dying off of the microorganisms increases as temperature drops (see Figure). E. coli and Citrobacter were found to be the most resistant at +5°C, Aeromonas and Alcaligenes were less resistant. In the control, where aqueous suspensions of microorganisms were kept at room temperature, there was virtually no change in number of viable cells (10^4-10^5 microbial bodies/mℓ) over a 12-13-day observation period. When stored at +5 to +6°C, significant decline in number of viable cells was demonstrated after 12-13 days, as compared to the baseline. Thus, by this time, at +5°C to +6°C, virtually no viable cells were demonstrable in suspensions of Alcaligenes cultures; there remained $7.0\cdot10^1$ microbial bodies/mℓ in the Aeromonas culture, $5.0\cdot10^2$ in Citrobacter and $4.0\cdot10^4$ in E. coli cultures. At -10°C temperature, there was complete inactivation of microorganisms in water infected with cultures of Aeromonas, Citrobacter and Alcaligenes within 5-6 days. A small number of E. coli ($3.0\cdot10^2$ microbial bodies/mℓ) survived at this temperature for 12-13 days. We were impressed by the fact that the decline in growth and viability of microorganisms under the effect of low temperatures was undulant (see Figure). In the presence of gradual decline in number of viable cells,

we observed periodic stimulation of their growth under the influence of repeated freezing after defrosting the media. This is confirmed in studies dealing with food preservation by this method [1]. The results of these studies revealed that, after Aeromonas and Alcaligenes cultures have been in a frozen state for 3-5 days and then thawed, no reactivation of cells was observed for 4 days, which was indicative of their death, rather than microbostasis.



Survival of different species of microorganisms at +5°C as a function of time

X-axis, time (h); y-axis, microorganism content in water, as related to control (%)
1) Aeromonas hydrophylla
2) Alkaligenes faecalis
3) Citrobacter freundii
4) E. coli

According to the results of studies dealing with long-term storage of samples of actual condensate of atmospheric moisture and regenerated water at room temperature, these media are beneficial for preservation of viable microorganisms at a high level--10^6-10^4 microbial bodies/mℓ, for 1 year. When tap water is deliberately infected with the same cultures, microbial contamination decreased from $2.8 \cdot 10^6$ to $4.0 \cdot 10^3$ microbial bodies/mℓ within 2 weeks. Since those initial products differed from one another in chemistry and levels of organic impurities (chemical oxygen minimum of the media constituted 250, 50 and 15 mg O_2/ℓ, respectively), it can be concluded that viability of micoorganisms was, to some extent, a function of these factors.

Micrococcus luteus (85%) and Alcaligenes faecalis (15%) were the most resistant forms of microorganisms in condensate, while this applied to Micrococcus luteus (99%) in regenerated water. However, we found that when atmospheric moisture condensate was stored in the refrigerator at +5°C for 1 week there was a decline to one-third in microorganisms content, as compared to the baseline. The condensate was virtually sterile after 2-3 months.

Thus, the fibdings are indicative of instability of microflora in a condensate of atmospheric moisture and regenerated water at low temperatures in a closed environment.

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DISCUSSIONS

UDC: 613.693-07:612.821.1/.3

EVALUATION OF PSYCHOLOGICAL FITNESS FOR FLIGHT WORK

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, Mar-Apr 87 (manuscript received 30 Apr 85) pp 89-92

[Article by V. I. Yevdokimov]

[Text] We construe the term, psychological fitness of pilots for flight work, as a specific qualitative mental state that provides for high efficiency and reliability of inflight pilot performance.

There are some difficulties involved in determining psychological fitness for flying. In the first place, flight work requires high-speed diagnosis and use of methods under airport conditions; in the second place, it is not at all easy to find informative parameters of preparedness, although various parameters of the subject's state could emerge as its criteria.

In some experiments, various techniques involving use of forms and apparatus were tested to determine readiness for flying. It was noted that the informative value of tests increases when they are combined with purposeful talks, skillful observation of a pilot's behavioral reactions, his emotions, form and content of speech [2].

Proceeding from the principle of the systems analysis approach, it can be said that mental fitness should be evaluated with consideration of social, moral-psychological, psychophysiological, intellectual and professional distinctions, as well as medical characteristics of flight personnel.

In this regard, projective methods may be useful; they determine the distinctive radius of thinking, the individual's relationship to people around him, rather than his different mental traits [5]. In order to assess the qualitiative and quantitative aspects of psychological fitness for flying, we used a flight variant of the thematic apperception test (TAT).

Methods

The flight variant of the TAT consisted of 10 picturee where, along with micro-social topics (intimate, family relations), which are present in the original TAT, there are pictures on aviation subjects.

Table 1. Evaluation of characteristics of heroes in pictures in variant of TAT

Score	Criteria				
	Motivation of flying	Confidence in performance	Activity (overall sthenia)	Discipline	Anxiety
9-8	SUBJECT OF STORY IS BASED ON DESCRIPTION OF FLIGHT WORK, SHOWS HIGH PROFESSIONALISM OF HERO'S MOTIVATION AND EXCELLENT KNOWLEDGE OF SPECIFICS OF FLIGHT WORK. MOTIVATION EMERGES IN THE FORM OF AN IDEAL	SUBJECT OF STORY IS BASED ON SUCCESSFUL AND EXCELLENT PERFORMANCE OF ALL OF HERO'S TASKS (FLIGHT ASSIGNMENT HANDLING DIFFICULT SITUATION ETC.)	HERO OF STORY IN PICTURE SHOWS VALOR AND COURAGE IN EMERGENCY SITUATIONS, HIGH DEGREE OF DILIGENCE AND PERSISTENCE IN REACHING SET GOAL. FEATURES OF LOFTY PATRIOTISM INHERENT IN HERO.	HERO OF STORY IS A HIGHLY DISCIPLINED INDIVIDUAL. HE COMPREHENDS CORRECTLY RULES OF FLYING AND ETHICAL STANDARDS, ADHERES TO THEM AND PREVENTS OTHERS FROM UNDISCIPLINED ACTIONS	SUBJECT OF TAT PICTURE HAS A SAD OUTCOME. HERO DIES AS A RESULT OF EXTRANEOUS CONDITIONS OR BY HIS OWN FAULT
7-6	AVERAGE KNOWLEDGE OF SPECIFICS OF PILOT WORK DISPLAYED IN TELLING STORY, THE SUBJECT IS BASED ON DESCRIPTION OF FLYING WORK. MOTIVATION MANIFESTED IN THE FORM OF DESIRES AND WISHES	HERO OF STORY DISPLAYS FAITH IN HIS ACHIEVEMENTS, IN SUCCESSFULLY LEARNING FLYING SKILLS. THERE MAY BE INSIGNIFICANT ELEMENTS OF DISTRUST IN AVIATION EQUIPMENT, BUT LONG TERM PROGNOSIS IS GOOD	IN THE SUBJECT OF THE STORY THE HERO DISPLAYS SUFFICIENT DILIGENCE AND PERSISTENCE. HE OFTEN HELPS OTHERS.	DISCIPLINED INDIVIDUAL CAPABLE OF DRAWING CORRECT CONCLUSIONS IN MATTERS OF NOT TOLERATING INFRACTIONS OF DISCIPLINE. THERE ARE ELEMENTS OF UNDERESTIMATION OF FLYING RULES (WITHOUT AFFECTING FLIGHT ASSIGNMENTS)	HERO OF PICTURE IS TROUBLED BY ANXIOUS THOUGHTS, POSSIBILITY OF SOME PROBLEM OR UNFAVORABLE OUTCOME WHERE THE MAJORITY VIEWS A FAVORABLE OUTCOME
5-4	SUBJECT OF STORY IS BASED ON DESCRIPTION OF PILOT'S WORK, BUT KNOWLEDGE OF WORK SPECIFICS IS BELOW AVERAGE. MOTIVATION MANIFESTED IN THE FORM OF AMORPHOUS INTEREST	HERO HAS BELOW AVERAGE CONFIDENCE IN SUCCESS OF PERFORMANCE. HE ADVANCES TOWARD GOAL BUT DOES NOT HAVE COMPLETE FAITH IN HIS ABILITIES. SOMETIMES THE SUCCESS OF HIS PERFORMANCE DEPENDS ON CONTINGENCIES	HERO OF TAT STORY HAS MODERATE DILIGENCE AND PERSISTENCE. IN DIFFICULT SITUATIONS HE IS NOT BRAVE OR DECISIVE ENOUGH. HE NEEDS THE HELP OF THOSE AROUND HIM	HERO OF STORY COULD INFRACT FLYING DISCIPLINE, PREFLIGHT REST SCHEDULE, ELEMENTS OF FLIGHT ASSIGNMENT FOR WHICH HE HAS BEEN PUNISHED. HE CAN DRAW CONCLUSIONS ABOUT AVOIDING RECURRENT BREACHES OF DISCIPLINE	THERE MAY BE ELEMENTS OF LACK OF CONFIDENCE, SENSE OF GUILT, WORRY ABOUT THE FATE OF THOSE CLOSE TO HERO. BUT WITH THE SUPPORT OF OTHERS HE CAN COPE WITH HIS TASK AND BE VICTORIOUS IN A DIFFICULT SITUATION
3-2-1	RELEVANCE OF HERO TO FLYING IS MERELY MENTIONED OR ELSE THE FLIGHT ASPECT OF PICTURE IS DISREGARDED	PLOT OF PICTURE IS BASED ON DESCRIPTION OF LOST WISHES AND HOPES. HERO HAS NO FAITH IN HIS OWN ABILITIES, IN HIMSELF, IN SUPPORTING HIS COMRADES OR IN ACQUIRING FLYING SKILLS	IN THE STORY PLOT THE HERO IS NOT PERSISTENT IN REACHING HIS GOAL. HE DISPLAYS ASTHENIC PERSONALITY TRAITS. HE IS UNDECISIVE, SLOW IN VITAL AND AVIATION SITUATIONS. LOW EFFICIENCY	HERO OF STORY COMMITS GROSS MISTAKES, BREAKS FLYING RULES, DISRUPTS FLIGHT ASSIGNMENTS BORDERING ON ACCIDENTS OR LEADING TO THEM WAS SUSPENDED FROM FLIGHT TRAINING	HERO OF STORY CAN OVERCOME ON HIS OWN DIFFICULTIES AND CAN COPE WELL WITH A DIFFICULT SITUATION. VIRTUALLY NO ANXIETY. EXOGENOUS CONDITIONS HELP HERO REACH HIS GOAL

Subjects of TAT variant pictures. 1) Single-seat combat aircraft. Flight under cloudy conditions. The pilot is looking down through the canopy. In the foreground is part of a plane with a cannon [or gun]. 2) Close-up of pilot's eyes; he is wearing an oxygen mask on his face, the top of which is attached to the headset. 3) In the foreground, there is a pilot (cadet) sitting near the chassis of a combat aircraft. In the background is the nose of the aircraft. A ladder is standing against the aircraft. 4) Destroyed aircraft. Cockpit has no canopy, part of the surfaces separated from the aircraft lying next to it. The aircraft is overgrown with grass and shrubbery. 5) Jet aircraft flying against background of clouds. 6) Instructor and cadet are arguing about something against the background of an aircraft. 7) Large aircraft flying with landing lights on, its outline is vague. 8) A cadet is sitting at a table near a window, there is an open book before him. A flying aircraft can be seen through the window. 9) Single-seat combat aircraft. Canopy is open. A pilot is sitting in the cockpit and talking with the aircraft engineer. An aircraft mechanic is pointing to something that is wrong. 10) Young girl in the foreground. Man walking toward aircraft in the background. Several jet aircraft in the distance.

In designing this TAT variant, we expounded the hypotheses that certain acute situations in life caused by the content of the pictures will elicit manifestation of appropriate psychological traits, the depth of which will depend on the subjects' individual psychological distinctions. This thesis was entirely confirmed during the period of standardization of the test [1, 3].

The experimentally stipulated activity in the test consisted of making up a story from the picture. The assignment emerged as a test for imagination, but the subject had to answer the following questions in his story: 1) What preceded the illustrated situation? 2) What is happening here? Who are these people and what are they thinking about? What is the outcome of the situation?

According to the system we adopted for interpretation of a story, we first assessed the psychological distinctions of the principal hero who, as it is assumed, resembles the subject, shares his feelings and has common goals. Then we examined the psychological traits of other characters in th· story, physical objects with which the main hero has to deal. We de rmined the extent to which they were instrumental in or prevented achievement of stipulated tasks. Special attention was given to indication of extent of problems along the hypothetical route, means of overcoming them, information about attitude toward flying profession.

All this served as the reference characteristics that reflected the motivational-personality traits of the subject.

The stories can be analyzed and interpreted in different ways. By reducing the total number of parameters to be assessed, we arrived at a few generalized parameters (flight motivation, confidence in successful performance, activity, discipline, anxiety), which can affect performance of a successful flight.

For mathematical processing of data, the psychological characteristics of subjects derived from the story were scored on a 9-point scale (9--highest

rating, 1--lowest). Table 1 lists the rating criteria. The score for each tested characteristic for different pictures were entered on the registration form [3]. The average score for a specific characteristic on all TAT pictures implied the intensity of this feature in a subject.

Table 2.
Conversion of sum of scores for flight to 9-point system in presenting 5 pictures of TAT variant

Score for hypothetical flight	Overall score
1	<79
2	80 -89
3	90 -99
4	100 -109
5	110—119
6	120 -129
7	130 -139
8	140 -149
9	>150

When giving an overall score for a hypothetical flight, we proceeded from the fact that the optimum level of manifestation of personality-motivation characteristics chosed for analysis of TAT stories has a beneficial effect on achievement of flight assignment. For this reason, the scores for these traits (motivation for flying, confidence in success, activity, discipline) were added up for all parameters in the pictures.

This sum represented the hypothetical formula for evaluation of psychological readiness for flying according to TAT. As a graphic example and for the sake of comparison to the rating for an actual flight, this integral result was converted to a 9-point system. The data on conversion of the sum of scores for the overall rating by the TAT are listed in Table 2.

Results and Discussion

In order to determine whether it is possible to assess psychological readiness for flying using the variant TAT we conducted several experiments. In the first one, we tested 2 groups of flyhng cadets (20-25 per group) at the end of preliminary flight training. They spent an average of 40-50 min to describe 5 TAT picutres, then went for a rest or a flight, and we interpreted their stories before the flights following a previously proposed system. In the second experiment, the subjects (22 pilots) did not write stories, but discussed orally for 7-10 min, each in turn, their impressions about preflight training, and the experimenter immediately entered the results on the registration form.

As a rule, testing by the TAT method was performed on individuals who required a more complete assessment of readiness for flying: those scheduled to solo for the first time, changing to a new more complicated form of training; individuals in whom a tendency toward flight accidents was noticed, or who had sustained some illnesses, and a few others (at the discretion of the commander and physician).

The test results were submitted to correlation analysis, with rating of an actual flight. The flight was rated on a 9-point system according to results of gathering information from pilot instructors, flight controllers, data from SARPP [expansion unknown] films and postflight debriefing.

A score of 9 points was given to a flight where the assignment was completed in full, flying technique was excellent, all specified mode parameters of the "sarpogram" were maintained, radio communications with the mission control team were appropriate, planning for landing was precise and landing was excellent (it should be noted that in our study, no one got this score). A score of 8-7 was given for a flight where the flight assignment was completed in full with insignificant deviations of flying technique which were recorded by the flying instructor or on SARPP film; appropriate radio communications, proper planning for landing and almost excellent landing. A score of 6-5 was given for a flight where the flight assignment was completed in full, but with deviations of mode parameters in flying technique and on SARPP films (they became the subject of discussion by the group commander at discussions between and after flights). Radio communications were appropriate, there was good planning for landing and the landing was good. A score of 3-4 was given when the flight assignment was almost entirely completed. Flying technique and the sarpogram showed deviations from specified parameters, which were discussed by the flight controller at postflight discussions. Some tension and imprudence were noted in the radio communications. Preparations for landing and landing were satisfactor. A score of 2-1 was given to a subject who did not perform the flight assignment. Deviations were recorded on SARPP films or by the flight control group, which were indicative of a possibility of flight accident. Radio communications were imprudent and strained speech was noted. The landing was poor.

We found that the overall evaluation of readiness for flying according to the TAT, flight motivation, confidence in successful performance and activity showed a positive and statistically significant correlation with the rating of a flight; there was a negative correlation between parameters of anxiety and quality of flight (Table 3).

Table 3. Correlations between data from TAT variant and rating of an actual flight

TAT characteristics	Coefficient of correlation	P
1. General evaluation of readiness for flying	0.51	<0.001
2. Motivation for flying	0.30	<0.05
3. Confidence in success	0.57	<0.001
4. Activity (general sthenia)	0.44	<0.01
5. Discipline	0.21	>0.05
6. Anxiety	-0.29	>0.05

The relationship to rating for an actual flight of discipline and motivation, which are important to a long-term forecast of flight performance, was unexpectedly low ($r = 0.42$, $P<0.01$; $r = 0.50$, $P<0.001$, respectively) [2, 4]. This can be attributed to the fact that discipline is a stable personality trait, and the subjects were rather disciplined individuals. As for motivation for flying, the criteria for evaluating it, which are based on the subjects'

knowledge about the distinctions of flight work, were not a strictly differentiating factor for most subjects. For this reason, the relationship of this characteristic to success of a specific flight was lower than in forecasting the success of all flight work.

In spite of the fact that it took 10-15 min to test one pilot under airport conditions, the time spent was fully justified, since information obtained with the TAT would be impossible to extract by other methods in a number of instances. It represented unresolved conflict situations at work and at home, doubt as to readiness for flying, which the "honor of wearing a uniform" prevented the subjects from overtly admitting; it also enabled us to assess the quality of preflight training (with resepct to developing confidence in having a successful flight). In 30-40% of the cases, the doubts voiced by cadets as to readiness for flying, according to the TAT pictures, were reflected in practice by flaws in flying technique noted by pilot instructors and the flight control group.

For example, 3d-year cadet S. did not adequately learn the landmarks in the flying zones. He concealed his ignorance from the instructor, since he was a group leader and for this reason was first to solo. During the TAT testing period (after preflight training), he displayed lack of confidence in fulfilling the flight assignment in some of the stories related to the pictures. The subject of the first picture was loss of orientation by the pilot due to poor flight training; the story for the third picture was based on guilt feelings for creating conditions for a flight accident, etc. Indeed, in the course of flights, this cadet showed deviations from the flying zone along the route of the civil aviation, and it is only when ordered by the flight control group did he correct his mistake in time.

Thus, using the flight variant of TAT one can detect psychological traits that are important to successful performance of flight assignments, which cannot be assessed by other methods in a number of cases.

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CURRENT EVENTS

UDC: 629.78:612.32/.33]:061.3(47+57)"1986"

SYMPOSIUM ON SPACE GASTROENTEROLOGY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, No 2, Mar-Apr 87 (signed to press 13 Feb 87) pp 93-94

[Article by K. V. Smirnov]

[Text] The first symposium on the topic of "Space Gastroenterology" convened in Ternopol within the framework of the 14th All-Union Conference on Physiology of Digestion and Absorption on 29 May 1986. The Unified Scientific Council for the Combined problem of "Human and Animal Physiology" of the USSR Academy of Sciences, Scientific Council for Physiology of Visceral Systems, the "Mechanisms and Patterns of Digestive System and Absorption Functions" Problem Commission, Ternopol Medical Institute, Scientific Research Institute at Kiev University imeni T. G. Shevchenko and the Lvov Medical Institute participated in organizing the conference.

A total of five basic and 8 poster papers were delivered and discussed at this symposium.

In the paper of K. V. Smirnov, he submitted data obtained during manned spaceflights and flights with animals on board, as well as from experiments that simulated flight factors. He described the phenomenology of changes in the digestive system. He noted that there is development of the gastric hypersecretory syndrome in weightlessness and during hypokinesia; he discussed the adaptive and compensatory capabilities of the digestive system during long-term spaceflights.

L. G. Goland-Ruvinova talked about adaptive changes in hydrolysis, transport and utilization of carbohydrates in hypogravity and hypokinetic conditions. The glycemic curves were studied as an integrative parameter of these processes. The change from normal motor activity to hypokinesia was characterized by a coordinated intensification of systems of cavitary and membrane hydrolysis of carbohydrates. For the next 2 months, there is depression of systems of hydrolysis and transport of carbohydrates. In the case of long-term weightlessness (hypokinesia), concurrently with depression of cavitary hydrolysis of carbohydrates, there is activation of the system of membrane digestion and active glucose transport.

The role of the system of digestive organs in lipid metabolism under hypokinetic conditions was the subject of the paper of I. L. Medkova. Studies were pursued

on man and animals. Activation of hydrolysis and absorption of lipids was observed up to the 30th day of hypokinesia. With increase in duration of the latter (60-120 days), there was dramatic decrease in activity of enzymes that hydrolyze lipids in digestive organs, impaired hepatic secretion of the biliary lipid complex, change in spectrum and nature of bile acid conjugate and in processes of lipid absorption. Development of special preventive and corrective measures is required to prevent these changes in the digestive conveyer of lipids.

The paper of N. N. Lizko dealt with the problem of intestinal microecology during spaceflights. It was shown that intestinal dysbacteriosis can develop during spaceflights of different duration. In such cases, a shortage of the "protective" groups of microorganisms could play the deciding role in development of dysbiosis. The paper validated the need to maintain stability of intestinal microbiocenosis during spaceflights.

A. P. Kuznetsov, A. A. Sveshnikov and N. V. Ofitserova did some interesting work dealing with investigation of human bile and pancreatic secretions in the presence of emotional stress caused by taking state tests or the first parachute jumps. The results of these studies revealed that emotional tension has a dissimilar effect on gastric and pancreatic function: basic gastric secretion diminishes appreciably, while pancreatic secretion undergoes virtually no change. Upon stimulation of digestive glands, the opposite response is observed. It was shown that the mechanisms of pancreatic secretion are generally much more resistant to emotional stress than gastric secretion. Muscular loads following emotional stress normalize secretory activity of the stomach and pancreas.

O. V. Zhiznevskaya delivered a paper dealing with the effect of hypokinesia on parameters of exocrine function of the liver. Investigation of bile synthesis under hypokinetic conditions in both man and animals revealed changes in the nature of conjugation of bile acids. It was shown that hypokinesia leads to increase in bile cholesterol content and decrease in bile lipid complex. The demonstrate changes could lead to decrease in colloid resistance of bile and increase in its lithogenicity.

The paper of V. N. Naydina and Ye. Ye. Zharkovskaya reported changes in fatty acid composition of human blood serum during 120-day hypokinesia. Of particular interest is the decrease in polyunsaturated linoleic acid. It was established that exercise used during hypokinesia had a normalizing effect on some changes in lipid metabolism.

The proteolytic systems of the digestive tract during exposure to weightlessness and hypokinesia were the topic of the paper of R. A. Pechenkina, N. P. Goncharova and Ye. I. Dobrokvashina. Only an increase in pepsinogen was found under the short-term effect of weightlessness and hypokinesia. With increase in duration of these factors, along with increase in pepsin secretion, there was depression of trypsin and dipeptidase activity in duodenal and intestinal contents. Animals showed a decrease in trypsin activity of pancreatic tissue and a shift of the proximal-distal gradient of dipeptidase activity.

The paper of V. N. Frolov submitted the results of studing correlations between intestinal microflora and digestive enzymes in man during simulation of some

of the physiological effects of weightlessness. Correlation analysis revealed a high correlation between the activity of some dipeptidases and amount of bacteriods, bifidobacteria, total amount of aerobic flora and certain other forms of microorganisms. Alkaline phosphatase activity showed a correlation with the quantity of lactobacilli, closteridia and urease-positive enterobacteria.

The paper of T. Ya. Struchkova, N. G. Shcherbakova and O. A. Smirnova dealth with ultrasonic studies of digestive organs in hypokinetic man. They found enlargement of the liver and pancrease, and decrease in acoustic density of the latter. It should be noted that these changes were less significant under the effect of physical training.

The paper of N. K. Trusenko and N. K. Permyakov submitted the results of morphological studies of the pancreas of hypokinetic animals. Histological and histochemical analyses made after 60-day hypokinesia revealed signs of chronic inflammation, sclerosis and lipomatosis in rats.

Questions of effect of graded exercise on lipase of duodenal contents and lipase of blood were discussed in the paper of O. A. Grigorovich, V. A. Gryaznykh and V. Ye. Tolchinskaya. It was established that a muscular load elicits changes in regulation of synthesis and secretion of lipases, and intestinal monoglyceride lipase is depressed to a greater extent than enzymes synthesized by the pancreas. The increase in phospholipase activity is related to some extent to intensification of hydrolysis and absorption of phospholipids.

The paper of A. N. Zavyalov, N. Yu. Shpanov and S. N. Markelov dealt with the effect of emotional tension on hydrolysis and absorption of carbohydrates in man. Emotional stress was studied while subjects were taking state tests. It was established that there was a higher level of glycemia following emotional tension than in a calm state. Emotional tension had an inhibitory effect on polysaccharide hydrolysis.

The symposium participants commented on its great importance.

There were active discussions and many questions were posed. Those who participated in the discussions commented on the high scientific and methodological sophistication of the papers.

BOOK REVIEW

UDC: 612.88

REVIEW OF POTEGAL BOOK ON SPATIAL ABILITIES OF MAN

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 21, Mar-Apr 87 (signed to press 13 Feb 87) pp 94-96

[Review by A. A. Gyurdzhiyan of book "Spatial Abilities. Development and Physiological Foundations," edited by M. Potegal, Academic Press, New York et al., 1982, 407 pages]

[Text] This collection presents the views of representatives of different specialties about the problem of spatial orientation. Its 15 chapters are grouped in 5 parts which deal with the following main directions: role of sensory systems, age-related aspects, role of heredity, involvement of cerebral cortex and subcortical structures in formation of human spatial orientation.

It can be considered a generally recognized fact that the sense of space is based on visual conceptions, whereas all other information about space is interspersed in the map of visual conceptions. This occurs with the participation of the parietal cortex. Motor activity, including movement of the eyeballs, is the most important elements of space perception (in particular, in the aspect of age-related psychology). We should also mention such important aspects as mental rotation and individual distinctions of strategy of spatial perception and spatial orientation. As for age-related psychology, we should mention the transition during individual development of man from the egocentric to external system of coordinates and correlation between these two strategies of spatial orientation.

Several chapters of this book were submitted in the form of papers in November 1979 at Columbia University at a conference that convened under the title of "Nervous and Age-Related Bases of Spatial Orientation." Each chapter has a comprehensive bibliography.

In the first chapter, its author H. A. Sedgwick describes the role of sight in spatial orientation: visual perception of the environment and its structures, man's ability to mentally turn the visual picture, perceive the mutual displacement of himself and objects around him in all planes, mechanisms of providing stability of the observed visual picture, tracking and pursuit movements of the eyeballs and autokinesia phenomenon.

B. Hermelin and N. O'Connor shed light on the encoding of spatial information coming from various sense organs in healthy children and children with

developmental defects. The coding strategy depends not only on modality of the sense organ, but verbal or nonverbal nature of information, prior experience, harmony in development or developmental defects in the child. However, it is certain that spatial coding of information is based on sight and visual conceptions, whereas hearing, for example, provides for information coding as a function of time.

E. Foulke discussed the distinctions of perception and recognition of the surrounding situation, as well as the displacement ability of blind pedestrians. Their limited ability to move about can be expanded if they are provided with appropriate information about the world around them by means of electronic systems of sensors. However, such devices have not yet been refined. To overcome the flaws in them, one must have good knowledge about the perceptual and cognitive functions of the blind.

In the second part, there are chapters dealing with development of spatial abilities in children.

J. G. Bremner discusses the conception of Piaget about formation in children of spatial conceptions, use by children of different ages of a system of spatial coordinates to define the location of objects around them and tactics for searching for the route toward a goal. The new data obtained by a number of researchers require that corrections be made in the conception of Piaget and its refinement.

H. L. Pick and J. J. Rieser dedicated their report to the ability of children to form in their mind a model of spatial orientation. They report on the results of a rather interesting study of navigation by aborigenes of Pulavit Island, who find the way in their dugouts in the Pacific Ocean to islands that are 1000-2000 km away from their island. They use the most varied reference points and systems of coordinates (position of the stars, direction and shape of waves, nature of wind, different islets along their route). There are some rather interesting orientation procedures used by children of different ages in a building or locality, and the landmarks and coordinates they use are also interesting. Previously, according to the conception of Piaget, two systems of coordinates were distinguished in age-related psychology: primitive egocentric and external. H. L. Pck and J. J. Rieser make a distinction between two immature forms of orientation (egocentric and according to various landmarks) and two more mature ones (correlation between onself and surrounding objects, self-contained external system of coordinates).

The article by R. G. Rudel discusses the difficulties involved in human perception and evaluation of slanted lines. While perception of horizontal and vertical lines is rather precise and accessible even to infants, it is a more complicated matter with slanted lines. This is related, to some extent, to inadequate verbalization of estimates of direction and extent of inclination of the lines. The oculomotor reaction plays a definite role in determining the inclination of lines, and apparently, this also applies predominantly to the right cerebral hemisphere. However, proper determination of the direction of inclination and mutual location of two oblique lines can only be the result of paired function of both hemispheres.

The investigation of R. Hart and M. Berzok dealt with the strategy used by children of different ages in forming a cognitive map of the geographic locality around them. The main tendency in development of spatial orientation is as follows: at first there is egocentric orientation, then the child selects several basic landmarks and constructs a cognitive map in relation to the latter; the most perfect form of orientation is the construction of maps on the basis of an external, abstract system of coordinates. However, the situation and external conditions play a major role in selection of strategy and system of coordinates; depending on them, the child uses a particular system of coordinates. For example, a child selects the appropriate landmarks on the basis of distinctions in a city map. He could remember either a specific road to the objet of interest to him, or else imagine the spatial relations between different objects as a whole. In each instance, one can detect the individual distinctions in the child's orientation.

Issues related to spatial abilities of adults and the role of heredity and sex are the topic of the third part of the collection.

M. C. Corballis discusses the bases of such an interesting psychological process as mental rotation of a visual picture. Perception, retention, internal conception and its reproduction are linked in this process. The author raises the question of which of these elements is propositional (abstractly logical) and which is analogical (analogous to an observed visual picture). He tends to believe that perception is more propositional, while reproduction and mental rotation are analogical.

M. G. McGee investigated the effect of genetic factors on spatial abilities. He describes sex-related differences in spatial oreintation, heredity of spatial abilities, their possible determination by some gene or other, in particular, by the sex X chromosome. He also believes that development of spatial abilities is closely related to specialization of the brain and development of functional asymmetry of cerebral hemispheres.

N. Newcombe also devoted his work to sexrelated differences in spatial abilities, difficulties and flaws of studies pursued in this direction.

The contribution of the cerebral cortex to organization of spatial abilities is discussed in the fourth part of the book.

Arthur Benton presented the historical aspect (over a period of 100 years) of development of conceptions of spatial thinking in neurological patients. He discusses the types of disturbances in spatial thinkinging (in particular, disturbances referable to body schema), the role of acoustic and tactile sensibility, the pattern of spatial disturbances in the presence of lesions in different parts of the cerebral cortex, visual-perceptive and visual-constructive forms of disturbances, as well as complex forms of disturbances that cannot be referred to any single sensory modality.

M. E. Golberg reported on his electrophysiological studies conducted on primates using a method of recording bioelectrical potentials of single nerve cells and fibers. He demonstrated that formation of perception of any object that appears in the field of vision is the result of interaction of different

afferentations: visual and proprioceptive (in particular from eyeball muscles). One can describe schematically the sequence of questions to which afferent systems respond in the following manner: What is reflected on the retina? What is the biological relevance of this object that has appeared in the visual field? How is this object located spatially in relation to an animal? How should the animal's appropriate motor actions be programmed? This integration and processing of sensory information (in particular, between the center and periphery of the retina) occur on different levels of the central nervous system. Integrating signals can mutually enhance or attenuate one another (lower or raise the sensibility threshold).

G. Ratcliff discussed the problem of dependence of the disturbances in spatial orientation on various cerebral lesions and adds clarity to relevant concepts and terminology used. He discusses in detail a relatively low level of analysis--sensory--and a higher one--perceptive integration in the central nervous system; he describes impairment of sensory analysis and visual localization of objects; he defines the role of the superior tubercles of the lamina tetragemina, precision of stereoscopic information; he cites examples of disturbances in perceptual integration (different forms of disorders of spatial perception and motor functions) related to a focal lesion in the right or left hemisphere, parietal or prestriate region in monkeys or humans. A distinction should be made between two spatial factors: visualization and orientation. Diverse manifestations of impaired spatial orientation are attributable in a rather complicated way to intertwining of functions of both hemispheres, and they require further investigation and systematization.

The fifth part of the book defines the role of subcortical structures in spatial abilities of animals. In Chapter 14 (D. S. Olton), there is description of the mechanisms of spatial organization of animal behavior. Good spatial oreintation of animals is based on ecologically determined spatial organization of behavior. The following elements are discussed: working memory of visited places; mutual location of these places and route to them from new places; choice of optimum (shortest) route between points.

The results of behavioral and neurological studies are subjitted. The latter, in particular, demonstrate that the role of the hippocampus in animals is apparently limited to providing for shoft-term working memory.

The last, 15th chapter (M. Potegal) deals with the role of the vestibular analyzer in the region of the neostriatum in spatial orientation. The author expounds the hypothesis of the role of the vestibular analyzer in navigational movement of animals. The vestibular system informs the central nervous system about the direction of movement, acceleration and speed for specific intervals, while the central nervous system effects integration, processing of this information and determines the trajectory of movement. Views are expressed concerning the possible involvement of different parts of the central nervous system in this function. Data are submitted, which are indicative of convergence of afferent signals of vestibular and somatosensory, vestibular and visual modalities. In the concluding part of this chapter, there is discussion of the possible "computing" role of basal ganglia of the central nervous system in vestibular navigation of animals. In particular, the role of the caudate nucleus is examined. Anatomical and electrophysiological investigations

confirmed the presence of vestibular-basal nervous connections. It can be assumed that involvement of the caudate nucleus in vestibular navigation is an element of egocentric spatial orientation, whereas the hippocampus and frontal cortex that became involved at a later phase of individual development contribute elements of nonegocentric, external (mainly visual) spatial orientation.

This book will be of considerable interest to a wide range of specialists concerned with problems of spatial orientation. It should be noted, that it concentrates chiefly on clinico-physiological and psychological aspects. The applied aspects of the problem of spatial orientation, which have drawn the attention of specialists in aviation, cosmonautics and industrial medicine, have been left virtually untouched in this book. Nevertheless, it will be beneficial to them also to read this book.

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